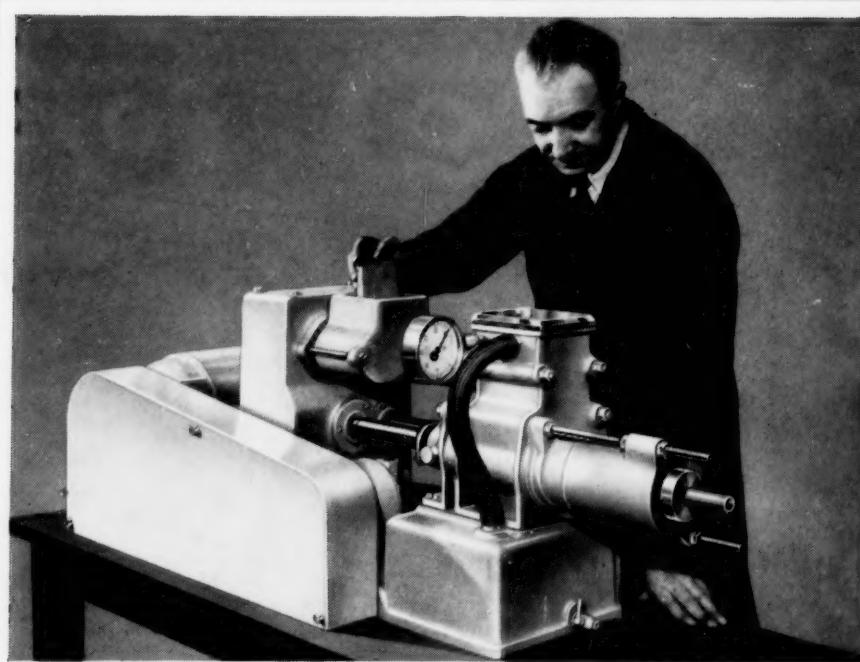




# CERAMICS

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No. 66 Vol. VI



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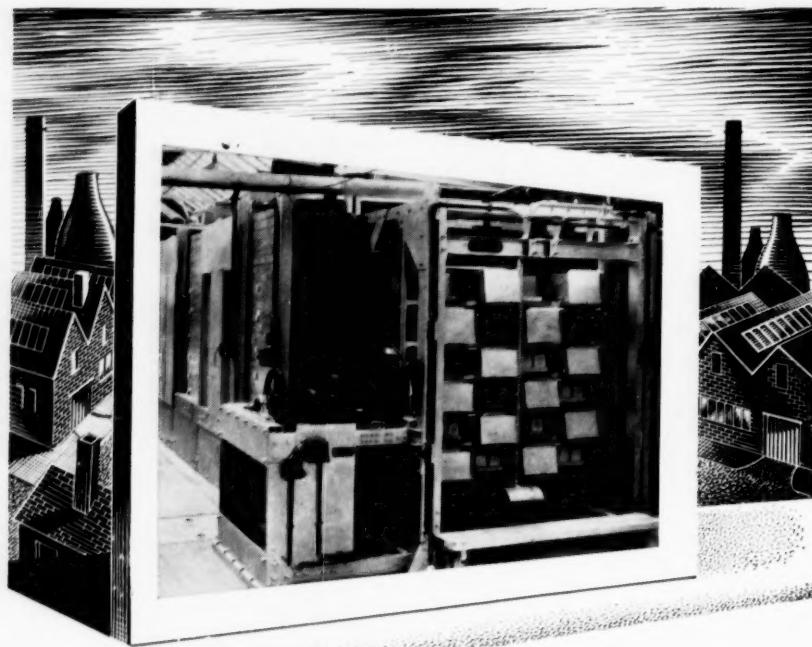
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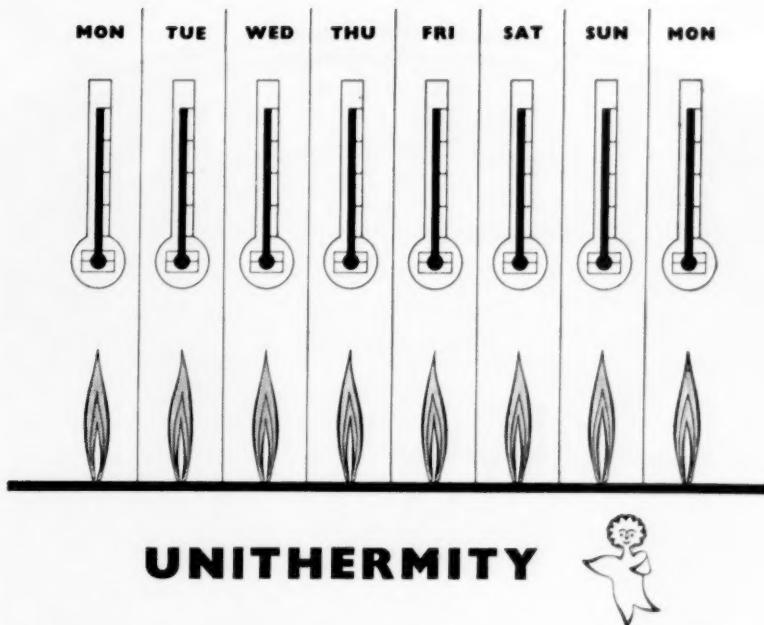
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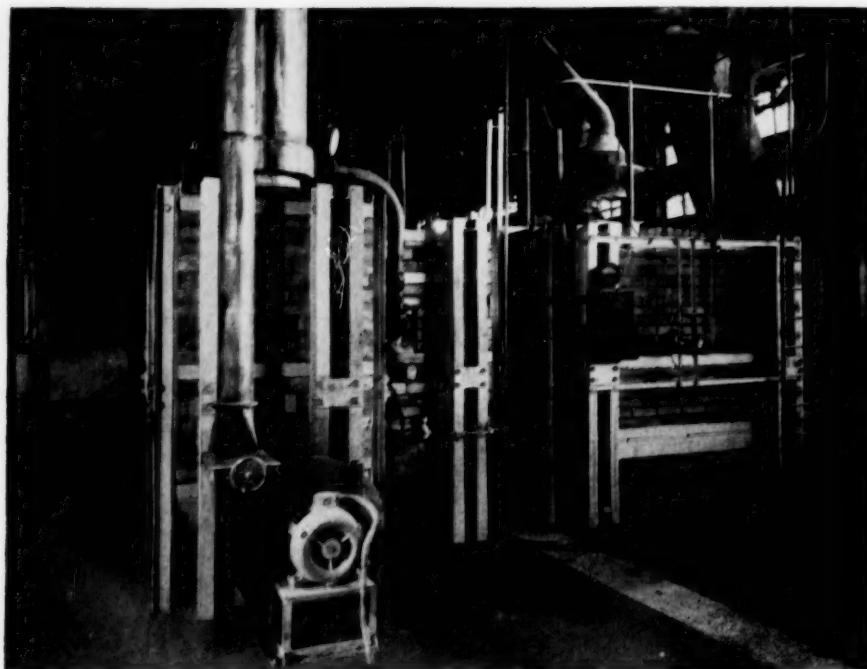


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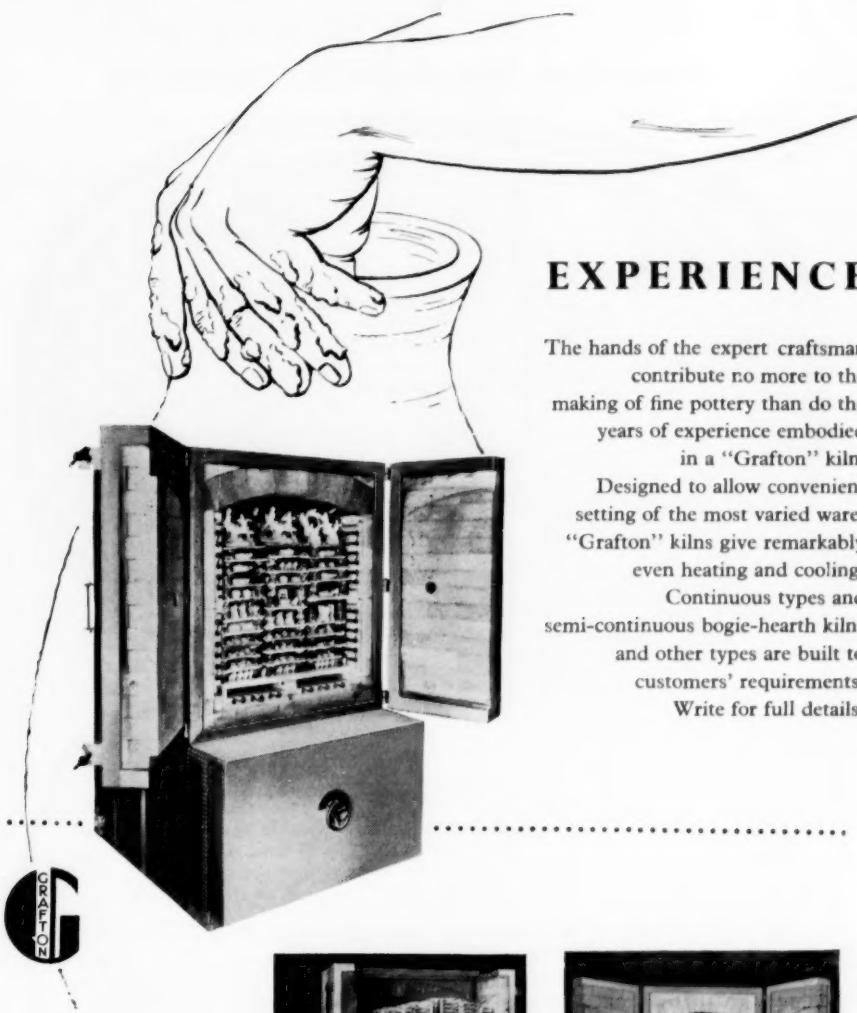
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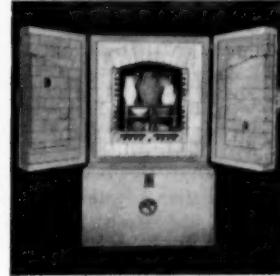
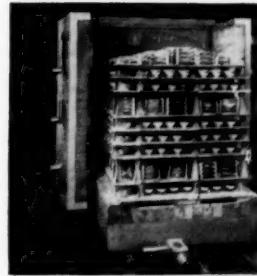
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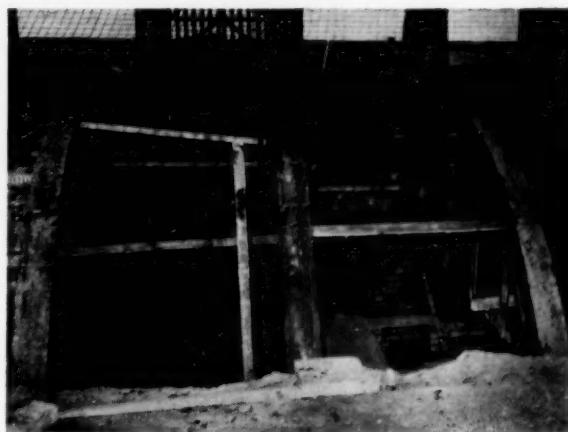
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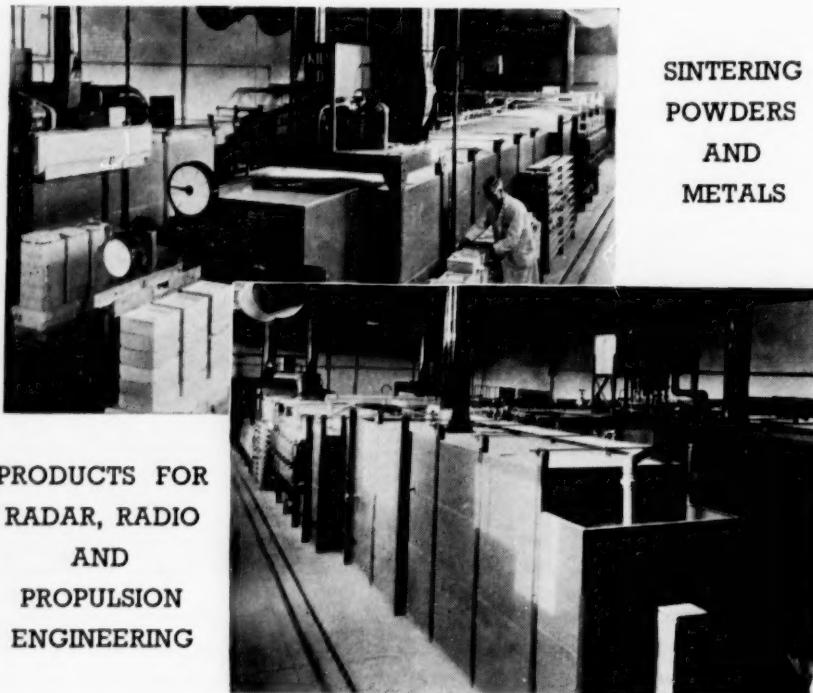
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# CERAMICS

A monthly journal covering the pottery, glass,  
heavy clay, refractory and silicate industries.

AUGUST 1954

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# Ceramics

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VOL. VI

AUGUST, 1954

NO. 66

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## Smoke and Finance

**POLITICAL and Economic Planning**, in their publication, "The Menace of Air Pollution," draw attention to the opinions of the medical fraternity as to the effect of smoke in the atmosphere upon health.

Undoubtedly in the pre-war years the potteries were among the worst offenders. However, in "Reports on the Progress of Applied Chemistry" reference is made to the reduction in atmospheric pollution arising from the introduction of gas and electric tunnel kilns in the potteries. In 1932 there was one gas tunnel kiln. In 1952 there were 229. In 1927 there was one electric kiln and in 1953 there were 111. The net result has been that the pottery industry has saved some 600,000 tons of coal each year, and, to quote from the above publication, ". . . has done much to reduce the smoke nuisance."

Unfortunately, however, this worthy end is double-edged, for it appears that there are many firms firing building materials and refractories where the capital investment which is necessary to change to continuous firing is beyond the means of the company itself. To some extent increased coal prices and public appreciation of the smoke nuisance activate against the use of coal in the intermittent kiln, and any such firms who feel that they can make a substantial saving in the amount of coal fired and who are not prepared for the immediate capital investment would do well to communicate with the National Industrial Fuel Efficiency Service, either at their Head Office at 71 Grosvenor Street, London, W.1, or in so far as North Staffordshire is concerned, with the Birmingham office at Lancaster House, Great Charles Street, Birmingham 3.

There is little doubt that the rise in the price of fuel has now made fuel conservation something of supreme importance to the ceramic industry. In Staffordshire, where town's gas for kiln firing has been adopted, the ovens have had their efficiency increased by increasing the pay load, reducing heat losses by better insulation, by greater utilisation of waste heat and by obtaining more efficient combustion. The pay load has been increased by using open placing or thinner cranks, whilst more efficient combustion has often been achieved by premixing gas and air since it is often impossible to mix these gases thoroughly in the normal type of burner.

Although electricity is still the most expensive fuel, kiln design has reduced the fuel consumption here to a large extent whilst open placing methods can be readily employed because there are no flames. What is more, the relatively high cost of continuous kilns has given popularity to the intermittent electric oven for glost and enamel firing in the small works. In effect, for a given output the cost of power to run such a kiln, although greater than for a continuous kiln, compares favourably in the overall financial picture because of the low initial cost.

# The Application of Phosphates in Ceramic Industries

by W. L. GERMAN, M.Sc., Ph.D., F.R.I.C.

THE use of bone ash in the manufacture of English bone china is well known. Other uses, which are perhaps not so familiar, are in special types of glasses, and in enamels; particularly in new types which are being evolved for use on metals like aluminium. In addition, aluminium phosphate finds some application as a bond in unfired refractory materials, and a sodium polyphosphate sold under the trade name of Calgon T finds application as a deflocculating agent, particularly for bone china casting slips.

### Bone China

The use of calcined bones, containing mainly calcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$ , with a little free lime, dated from the discovery of Josiah Spode in ca. 1800.

The standard recipe is:

China clay	...	...	25%
Bone	...	...	50%
Stone	...	...	25%
or sometimes:			
China clay	...	...	23%
Ball clay	...	...	2%
Stone	...	...	25%
Bone	...	...	50%

The role of the phosphate in the body has been the subject of several investigations. Earlier workers found that a percentage of it seemed to act as a flux, forming a glassy substance with the other ingredients, while the remainder acted as a refractory.<sup>1</sup> The most fluid glass was given the composition  $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot (\frac{1}{2}\text{P}_2\text{O}_5)$ .<sup>2</sup> The nature of the crystals dispersed in the bone china body was difficult to determine since they were very fine. The latest work indicates that they are a calcium phosphate,  $3\text{CaO} \cdot \text{P}_2\text{O}_5$ , anorthite,  $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ , and possibly a little silica.<sup>3</sup> The translucency of such ware seems to be re-

lated to the relatively high refractive index of the lime-silica-phosphate glass formed in firing.

The calcination and preparation of the bone for use in making the bone-china body needs care, and this has been fully described in a previous issue of CERAMICS.<sup>4</sup>

Various attempts at substituting mineral phosphates for calcined bone in bone china have not hitherto been very successful. The firing range of such bodies seems to be very short, and it is difficult to avoid losses due to crooked ware.<sup>5</sup> Moreover, the plasticity is very low.

### Phosphates as Opacifiers

Calcium phosphate is sometimes used as an opacifier in enamels. Its refractive index is 1.58-1.62, compared with 1.50-1.55 for the glassy phase usually present. It is not, therefore, such a good opacifier as the more usual ones like tin, antimony, and zirconium oxides. It is, however, a relatively cheap material, and various research papers and patents have described its use for opacification. A list of these is given in a paper entitled, "Future of Phosphate Enamels based on past experience of Phosphate Glazes," by Dr. P. A. Huppert.<sup>6</sup> These describe the addition of phosphates as opacifiers both to the frit and as mill additions. As examples of the former we have U.S. Pat. 2,324,812 (20/6/43), W. J. Bahnsen and E. E. Bryant, which describes frits containing 10-20 per cent. zirconia ( $\text{ZrO}_2$ ) and about 1.7-5 per cent.  $\text{P}_2\text{O}_5$ , U.S. Pat. 2,339,260 (18/1/44), L. J. Frost and C. H. Commons, covering frits containing 7-15 per cent. zirconium silicate and 0.25 to 4 per cent. aluminium phosphate, and U.S. Pat. 2,436,825 (2/3/48), H. D. Prior, for a super opaque vitreous enamel in

which the frit compositions were defined as:

Na <sub>2</sub> O	...	3-6 per cent.
K <sub>2</sub> O	...	1-5 " "
Li <sub>2</sub> O	...	3-5 " "
BaO	...	1-3 " "
CaO	...	1-5 " "
ZnO	...	5-7 " "
Bi <sub>2</sub> O <sub>3</sub>	...	7-9 " "
Al <sub>2</sub> O <sub>3</sub>	...	20-25 " "
P <sub>2</sub> O <sub>5</sub>	...	22-25 " "
SiO <sub>2</sub>	...	7-15 " "
F <sub>2</sub>	...	3-5 " "
ZrO <sub>2</sub>	...	6-10 " "

P<sub>2</sub>O<sub>5</sub> and Li<sub>2</sub>O could be introduced by using 42-47 per cent. of amblygonite.

An example of a phosphate mill addition is that of W. J. Baldwin, U.S. Pat. 2,483,393 (4/10/49), which describes a mill addition opacifier made from 10-40 per cent. TiO<sub>2</sub>, 25-65 per cent. Al<sub>2</sub>O<sub>3</sub>, and 24-45 per cent. P<sub>2</sub>O<sub>5</sub>. This was used with a standard zirconium opacified frit.

Various other patents describe the use of barium and strontium phosphates in place of calcium phosphate as opacifiers, or of mixtures of these. For these Huppert's paper (loc. cit.) should be consulted.

### Use of Phosphates in Opaque Glazes

W. H. Earhart<sup>7</sup> has described work on the use of phosphates for opacifying leadless glazes fired in a tunnel kiln and maturing at Cone 11. These glazes were (A):

0.15 NaKO	0.35 Al <sub>2</sub> O <sub>3</sub>	0.25 Li <sub>2</sub> O
0.50 CaO		0.55 Na <sub>2</sub> O
0.25 ZnO		0.417 Al <sub>2</sub> O <sub>3</sub>
0.10 MgO		0.208 B <sub>2</sub> O <sub>3</sub>

and (B):

0.28 KNaO	0.34 Al <sub>2</sub> O <sub>3</sub> . 2.8 SiO <sub>2</sub>	0.20 ZnO
0.42 CaO		0.10 MgO
0.20 ZnO		
0.10 MgO		

Four per cent. of the phosphate was added to each glaze. Those tried were tricalcium phosphate, calcium pyrophosphate, magnesium phosphate, zinc phosphate, aluminium phosphate and lead phosphate. In glaze (A) good results were obtained except with aluminium phosphate, where the Al<sub>2</sub>O<sub>3</sub> added made the glaze immature. Good results were also found with glaze B, except that lead phosphate gave an opalescence. Calcium pyrophosphate was claimed to be as

good as tin oxide. The composition of the glaze is important, as with certain commercial glazes of the lead and leadless types calcium pyrophosphate and phosphate were ineffective as opacifiers.

### Phosphates in Low Melting Enamels

The application of enamels to non-ferrous metals like aluminium has been the subject of development work in the U.S.A. in recent years, particularly for the production of sheets which can be used for covering the steel frames of buildings. Construction in this medium (with suitable insulating backing) offers attractions in that considerable reduction in weight is possible over traditional methods, and this is reflected in less consumption of steel girders and a reduction of building costs. Aluminium being a low-melting metal, it was necessary to develop very fusible enamels which could be applied in the region 500-550° C. Early attempts at enamelling aluminium used lead-containing frits, and these are still being applied. To avoid the disadvantages attendant on the use of lead compounds, attempts have been made to evolve leadless types. Phosphate enamels appear promising in this respect. A list of references to these is given in an article in CERAMICS published in March, 1954.<sup>8</sup> One set of workers<sup>9</sup> have based their experiments on a frit of composition:

0.25 Li <sub>2</sub> O	0.417 Al <sub>2</sub> O <sub>3</sub>	0.625 P <sub>2</sub> O <sub>5</sub>
0.55 Na <sub>2</sub> O		0.208 B <sub>2</sub> O <sub>3</sub>
0.20 Na <sub>2</sub> F <sub>2</sub>		

This was used over a special ground coat to avoid boiling.

Opacifiers could be added at the mill and also colouring oxides. This type of enamel resists scratching by a knife and gives reasonable acid resistance. Some improvement in resistance to weathering is desirable, and work is proceeding to this end. Another frit which has been described<sup>10</sup> for acid-resisting cover coat is also a silica-free aluminophosphate type. The batch composition is given as:

Potassium nitrate	...	4.6 per cent.
Potassium carbonate	...	3.2 " "
Borax crystals	...	13.2 " "
Sodium carbonate	...	7.3 " "
Cryolite	...	4.8 " "
Zinc oxide	...	3.7 " "
Alumina hydrate	...	17.9 " "

## CERAMICS

Mono. Ammonium Orthophosphate 39.6 per cent.  
 Zirconium oxide ... 5.7 " "  
 This was opacified with antimony oxide, zirconia, and barium molybdate as mill additions, thus:

### Enamel batch

Frit	100
Clay	4
Sod. nitrite	0.5
Zirconium opacifier	4.0
Barium molybdate	1.5
Antimony oxide	1.5

### Phosphate Glasses

A large variety of glasses containing phosphates is now available. The addition of phosphates covers the following applications:

- Opal glasses in which the phosphate acts as an opacifier.
- As an ingredient in luminescent and phosphorescent glasses.
- In glasses which transmit ultra-violet light.
- In glasses of high electrical resistance.
- In special glasses which have to withstand the action of metal vapours in lamps.

A list of patents and references to these applications is given in Dr. P. A. Huppert's article, quoted above.

### Opal and Opaque Glasses

Opal glasses have been described in which bone ash, potassium metaphosphate, zinc phosphate, and barium pyrophosphate have been incorporated into the batch to give opacification. The following examples of opal glasses made with bone ash are given in "A Text Book of Glass Technology" (Hodkin and Cousen, London, 1925).

	(1)	(2)	(3)
Sand	1,000	1,000	1,000
Potash	450	100	300
Soda ash	30	245	70
Bone ash	260	220	300
Lime spar	30	180	100
Nitre	15	20	—
Red lead	5	—	—
Arsenious oxide	15	—	—
Manganese dioxide	1	—	—
Borax	—	20	—

Other phosphates can replace bone ash as opacifiers such as sodium phosphate,  $\text{Na}_2\text{HPO}_4$ , potassium, metaphosphate, zinc phosphate, and

sodium pyrophosphate,<sup>12</sup> and barium pyrophosphate.<sup>13</sup> Apatite has also been used to promote opacification in glass. Boric acid intensifies the action of bone ash and in silicate types opacified with phosphate the presence of lead oxide is favourable. Barium oxide comes next on the list. Similarly, in borosilicate glasses lead and barium oxide assist opacification and zinc oxide is also favourable to a lesser degree. Opalescence is apparently due to a suspension of  $\text{P}_2\text{O}_5$  in the glass.<sup>14</sup>

### Optical Glasses

According to N. J. Kreidl and W. A. Weyl,<sup>15</sup> sodium phosphate was first added to English flint glass to improve its colour as far back as 1854. Phosphate glasses have a larger refractive index than silicate glasses of the same dispersion and are better for achromizing borate flint glasses. Optical phosphate glass was used in 1902 to produce anastigmatic objectives superior to those then in use, but owing to the fact that the phosphate glass was not very durable to weathering and chemicals, they were not produced for long. Kreidl and Weyl quote two examples of optical phosphate glasses: (i) a light phosphate crown of refractive index  $n_r = 1.5159$ , and (ii) a dense barium phosphate crown  $n_r = 1.5760$ .

	(i)	(ii)
$\text{P}_2\text{O}_5$	70.5	54.0
$\text{B}_2\text{O}_3$	3.0	3.0
$\text{K}_2\text{O}$	12.0	—
$\text{MgO}$	4.0	—
$\text{BaO}$	—	40.0
$\text{Al}_2\text{O}_3$	10.0	1.5
$\text{As}_2\text{O}_3$	0.5	1.5

### Glasses to Give Transmission to Ultra-Violet Light

Phosphate-containing glasses have been widely described in the literature for this application, and this has been one of the causes of revival of interest in phosphate glasses. The phosphate glass crowns first made around 1888 were found to be superior to other optical glasses for ultra-violet transmission, but after the discovery of the beneficial effects of ultra-violet light to the human body around 1925, interest was well aroused in the need for a glass of reasonable price which would give good transmission to this radiation. Early types of glass were

prone to divitrification, or lost their power of transmitting ultra-violet radiation after prolonged exposure to sunlight.

A new type of glass capable of transmitting ultra-violet light was introduced by H. P. Hood<sup>12</sup> in 1926 and called *Corex*. It consisted of calcium phosphate with small amounts of boric oxide, alumina and silica. D. Starkie and W. E. S. Turner<sup>13</sup> give the analysis of a *Corex* type of glass as:

P <sub>2</sub> O <sub>5</sub>	66.45	per cent.
CaO	25.16	" "
B <sub>2</sub> O <sub>3</sub>	4.63	" "
SiO <sub>2</sub>	2.12	" "
Al <sub>2</sub> O <sub>3</sub>	0.37	" "
MgO	0.60	" "
Na <sub>2</sub> O	0.56	" "
Fe <sub>2</sub> O <sub>3</sub>	0.03	" "

This glass was not as stable chemically as later types which were evolved. Types based on aluminium and barium phosphate were evolved in Germany which, in addition to giving excellent transmission to ultra-violet light had improved chemical properties. Moreover, the softening point was such as to permit the usual glass-blowing operations. H. G. Grimm and P. A. Huppert have patented compositions based on aluminium orthophosphate. These glasses are resistant to water. Workability was improved by additions of B<sub>2</sub>O<sub>3</sub> and zinc oxide giving resistant glasses which transmit ultra-violet light and soften at temperatures as low as 400° C.<sup>17</sup> W. Kaufmann and E. Bungartz<sup>18</sup> have claimed that phosphate glasses using barium compounds have some advantages over calcium compounds. Various other patents on this subject are detailed by P. A. Huppert (loc. cit.).

### Fluorescent Glasses

Fluorescent glasses can be produced by adding an activating agent to phosphate glasses. Thus W. Kaufmann, L. Eckstein and K. Rosenberger<sup>19</sup> found that by introducing tin oxide fluorescent phosphate glasses were obtained.

Other patents taken out in this country cover luminescent materials made from alkaline earth halogenophosphates activated with antimony manganese, e.g., 3Sr<sub>2</sub>(PO<sub>4</sub>)<sub>2</sub> · SrF<sub>2</sub> or

6Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> · Ca F<sub>2</sub> · CaCl<sub>2</sub> activated with 2.6 per cent. Sb and 0.10 per cent. Mn or 2.5-7.5 per cent. Bi and 0.10 per cent. Mn.<sup>20</sup> Activation of calcium phosphate (with little calcium sulphate) by thallium and of calcium silicate by manganese and lead are also patented.<sup>21</sup>

### Chemically-resistant Phosphate Glasses

The problem of the low chemical resistance of the early phosphate glasses has been mentioned. In 1924 E. C. Buck described the use of glasses made mainly from the metaphosphates of the alkaline earth metals with additions of aluminium phosphate. Kreidl and Weyl (loc. cit.) quote the following examples of these glasses which were resistant to hydrofluoric acid and used for dishes, bottles, etc.:

	P <sub>2</sub> O <sub>5</sub>	CaO	Al <sub>2</sub> O <sub>3</sub>
(i)	77.46	10.18	12.36
(ii)	73.15	23.77	3.08

Other glasses resistant to hydrofluoric acid based on aluminium phosphate with other metallic oxides are given in P. A. Huppert's article,<sup>6</sup> which also mentions phosphate glasses suitable for metal vapour lamps because of their resistance to light metal and other vapours.

### Glasses for Heat Absorption

Glass filters to absorb heat from lamps are often invaluable in many instruments. Such compositions are based either on phosphate glasses, e.g.:<sup>22</sup>

H <sub>3</sub> PO <sub>4</sub>	81
Al <sub>2</sub> O <sub>3</sub>	7.5
BaCO <sub>3</sub>	4.5
Fe <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> · 8H <sub>2</sub> O	1.10

Or on more conventional glasses containing appreciable amounts of phosphate, e.g.:<sup>23</sup>

P <sub>2</sub> O <sub>5</sub>	70.7	40.0
B <sub>2</sub> O <sub>3</sub>	4.0	30.0
Al <sub>2</sub> O <sub>3</sub>	10.0	10.0
MgO	4.0	10.0
ZnO	1.0	—
K <sub>2</sub> O	10.0	10.0
FeO	2.5	2.5
	102.2	102.5

## CERAMICS

### Aluminium Phosphate as a Bonding Agent

In recent years aluminium phosphate, which forms a viscous liquid, has been used as a bonding material for unfired and refractory materials made from materials lacking in plasticity. On subsequent firing decomposition takes place with the liberation of phosphorus oxide and leaving alumina in the material. This is an advantage in improving its refractoriness.

It can thus be seen that phosphates have many important applications in the ceramic field. For further information the reader is recommended to consult the references quoted below.

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**New Indian Porcelain Factory.**—With an extensive programme of hydro-electric development and an ever-widening use of electricity, India's requirements of electrical components parts and insulators are likely to increase considerably in the next few years.

To meet the growing demand for electro-porcelain from home production a new Government porcelain factory is to be erected at Bangalore, the foundation

stone for which was laid by the Rajpramukh of Mysore on 7th July.

Estimated to cost Rs. 6·3 million, the new factory, which is an expansion of an existing smaller factory, is being undertaken with the help of the technical collaboration of a Japanese firm, with whom the Indian Government entered into a ten-year agreement on 31st March this year.

When the expansion has been completed the annual production of electro-porcelain is expected to be increased from the present 300 tons to 2,500 tons, or an output equivalent to Rs. 10 million in value. Products and quantities expected to be manufactured are: 1,400 tons of 10 in. suspension insulators, 650 tons of pin-type insulators, 150 tons of pot-type insulators and 300 tons of other tube insulators for transformer and allied requirements.

**General Refractories Ltd.**—Mr. Geoffrey G. Abraham has been appointed to represent General Refractories Ltd. in the Middlesbrough Area in succession to the late Mr. C. Ramsden.



# Specialised Refractories and Fuel Economy

## Considerable Savings Achieved

ALTHOUGH specialised refractories have been manufactured in this country for over half-a-century, their applications have, up to now, been limited to a rather narrow range of duties. In the construction of many of the furnaces used in industrial processes ordinary fire-brick alone has been employed, resulting in the inefficient use of the heat produced, since as much as 50 per cent. of it is often absorbed by the furnace structure or conducted through it and passed into the surrounding atmosphere.

At a time when fuel economy is of vital importance to Britain, as stressed by the recent report of the Ridley Committee, such practice is not only wasteful of precious coal and other fuels, but cuts straight across the need for increasing productivity and reducing production costs.

### Recent Refractory Research

To combat this inefficiency a good deal of investigation has gone into the production of new and specialised refractories. As a result of this research two new groups of materials have been developed. One of these groups embraces high-temperature insulating firebricks, capable of being exposed to furnace atmosphere, by means of which heat losses can be substantially reduced, particularly in the case of gas- or oil-fired appliances. On the other hand, greater efficiency can be achieved in certain cases by using a superior type of firebrick of the second group capable of withstanding the very arduous conditions often encountered which frequently call for particularly high volume stability at high temperatures and/or high hot strength with reasonable resistance to both physical and thermal spalling.

### Cause of Heat Loss

Heat losses imply heat transfer from one body to another. This can happen in three ways, viz., conduction, convection and radiation. In dense solids heat flows by conduction, and this is especially true of metals. Though most

refractory materials have thermal conductivities lower than metals, serious heat losses can occur by conduction through furnace walls. Still air has a very low thermal conductivity, but since air movement is normally difficult to prevent, heat loss by convection occurs in this way. If, however, the air can be confined to a small space, the convection effect is diminished. Heat flow also takes place across air spaces by radiation and varies as the fourth power of the absolute temperature; thus the heat transmitted by radiation increases rapidly with rise in temperature. But, divide a space into a large number of small divisions so that the temperature drop across each small division is itself small, and the heat transmitted across the space by radiation will be much reduced.

### Porous Type Refractories

In developing the first group of new refractories, therefore, it was found essential to use a material of porous structure, and, indeed, it is from this quality that all insulating materials derive their high resistance to heat flow. To produce such porous effect in refractory materials the clay is mixed with finely divided combustible materials, which are subsequently burnt out during firing, leaving a cellular structure, the size of whose pores and their degree of interconnection is of prime significance in regard to its insulating qualities.

Because of the high porosity of such a brick, bulk density is correspondingly low and its heat capacity is only one-third that of an ordinary firebrick, a fact of some importance in furnaces which operate intermittently, since, in such installations, much heat is often lost in raising brickwork to operating temperature and similarly through cooling to atmosphere when the furnace is shut down.

### Comparison Tests

By using this new type insulating brick in conjunction with ordinary firebrick in a number of types of furnace structures some interesting results have been obtained. In arriving at the figures shown

## CERAMICS

in Table 1, heat losses have been calculated for steady state or equilibrium conditions. Furnace temperatures have been based on 2,400°F. (1,316°C) and heat loss to still air at 65°F.

From Table 1 it will be seen that, in comparing No. 1 and No. 2, the application of a 4½ in. porous insulating material behind a wall of 13½ in. firebrick reduces the steady state conduction loss by 56 per cent., but actually increases the heat stored in the brickwork by 46 per cent. This effect is also apparent, though to a less extent in wall No. 3. In the first four types it will be seen that the mean temperature of the firebrick wall is appreciably raised with progressive increase in insulation and care should be taken that the refractory wall will withstand such conditions. When, as in No. 5, the insulation is applied directly on the hot face of the furnace, a substantial reduction in heat stored is achieved, and, at the same time, conduction heat losses are relatively low. The storage loss relative to the 13½ in. firebrick wall shows a decrease of 78 per cent. and conduction loss a decrease of 56 per cent. An increase in the thickness of the porous insulation to 13½ in., as in No. 6, causes, as would be expected, some increase in heat stored, but re-

duces external heat loss by 70 per cent.

In the case of continuously-operated furnaces, where heat storage loss is of relatively little account, a dense refractory wall lined with appropriate grades of insulation is most suitable.

### Intermittent Furnace Heat Loss Data

Calculating combined storage and conduction heat losses in intermittent furnaces is, however, a more difficult and complicated matter, and, in many cases, precise conditions of heating and cooling are not available to enable reasonable estimates to be made. Data has, however, been compiled empirically from which estimates have been prepared of the heat losses to the structure of intermittent furnaces operating on single, double or treble daily shifts, five days a week, with week-end shut-down. Five types of wall structure have been considered and the combined weekly heat storage and conduction loss per square foot of wall area investigated. The results are given in Table 2.

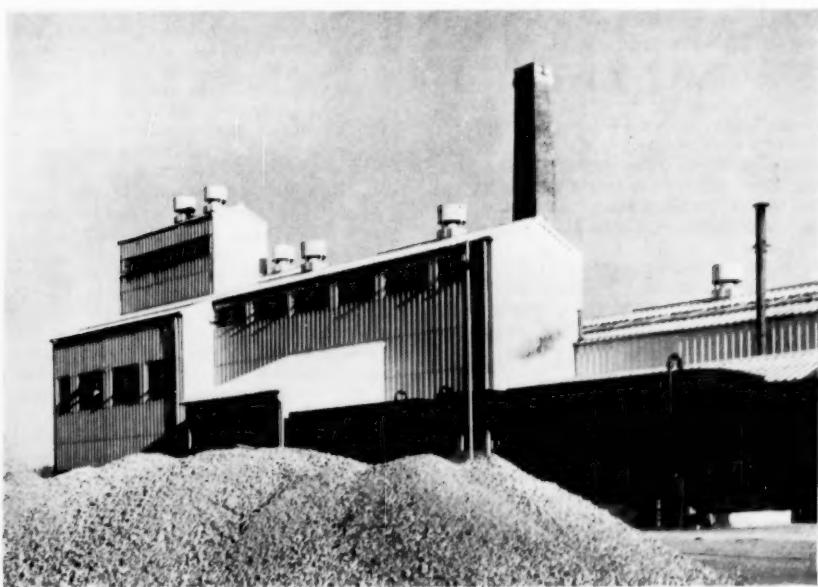
The marked effect of the use of a lining of porous insulating brick is clearly shown, the maximum saving being attained with a 13½ in. insulating wall. In this case the heat loss to the furnace

TABLE I.

Type of furnace wall structure	Interface Temp. °F —	Interface Temp. °C —	Cold face Temp. °F 450	Cold face Temp. °C 232	Heat storage B.Th.U/ sq. ft. 52,000	Conduction loss B.Th.U/ hr. sq.ft. 1,430
1. 13½ in. firebrick	—	—	450	232	52,000	1,430
2. 13½ in. firebrick plus 4½ in. porous insulating brick	1,550	843	280	138	76,250	630
3. 9 in. firebrick plus 4½ in. porous insulating brick	1,725	940	310	154	54,700	750
4. 4½ in. firebrick plus 9 in. porous insulating brick	2,150	1,177	260	127	38,050	550
5. 9 in. porous insulating brick	—	—	280	138	11,250	630
6. 13½ in. porous insulating brick	—	—	230	110	16,450	430



Main entrance to Neston. The administration block can be seen on the right, and on the left is the specialised refractories production shop



The calcinating plant and part of the raw materials stockpile

TABLE 2.

## Thermal Properties of Various Wall Construction Used in Intermittent Furnaces.

Wall Construction	Hot Face Temp. Deg. F.	Inter- face Temp. F.	Cold Face Temp. Deg. F.	Steady State Heat Conduction Storage Loss B.Th.U/ sq. ft. sq. ft. hr.	Weekly Heat Loss to Structure per 5 Day Week 1 Shift/Day B.Th.U/ sq. ft.	1 Shift/Day B.Th.U/ sq. ft.	2 Shift/Day B.Th.U/ sq. ft.	3 Shift/Day B.Th.U/ sq. ft.
13½ in. FBK.	2,400	—	445	51,500 1,450	130,000	169,000	192,000	
13½ in. FBK. + 4½ in. M.I.23	"	1,676	257	78,050 540	111,400	102,100	98,000	
9 in. FBK. + 4½ in. M.I.23	"	1,848	276	55,550 610	108,300	106,200	100,500	
4½ in. FBK. + 9 in. M.I.23	"	2,212	226	36,200 420	71,300	70,800	67,900	
9 in. M.I.28	"	—	284	11,400 640	51,500	72,100	83,000	
4½ in. M.I.28 + 9 in. M.I.23	"	1,965	205	16,300 340	37,400	44,200	47,600	

structure is reduced by 71 per cent. for a one-shift, 74 per cent. for a two-shift, and by 76 per cent. for a three-shift, five-day week, relative to the 13½ in. firebrick used alone.

#### Economics Achieved

As an example of the economy effected by the use of a low heat-storage refractory in an intermittent furnace, a case is outlined below. Where 13½ in. thick firebrick walls and roof have been replaced by 13½ in. porous insulating material, an estimated overall saving of £63 per 100 sq. ft. of wall area has been calculated for the first year's operation of the furnace, representing a difference between reduced fuel costs and increased insulation costs. The annual saving after the first year would exceed £200 per 100 sq. ft. of wall area. Details of the case are given in Table 3.

#### Additional Saving

Table 3 does not, however, take into account further economies due to the quicker heating and cooling or to reduced heat loss to the flue gases as a result of the lower rate of firing in the insulated furnace. Other advantages, apart from fuel saving, include time saving, often greater hearth area (giving higher productivity, less supporting steel-work required and lighter foundations permitted).

#### Dense Type Refractories

The second group of new refractories being developed are of the dense structural type and are intended to fill a gap hitherto existing in the firebrick range.

Capable of standing up to arduous conditions they will meet the need of the more difficult service applications. Having very low after-contraction at temperatures up to 1,600° C., with high resistance to deformation under normal loads at temperatures in excess of 1,600° C., and high mechanical strength with good resistance to physical spalling, they ensure good wearing qualities. They are particularly suited for such applications in the iron and steel industry as side walls of reheating furnaces, reverberatory furnaces, billet heating furnaces, regenerator construction and checkers, etc. They are similarly suitable in boiler furnaces of all types, including solid or pulverised fuel or oil-fired units, for lining combustion chambers, target walls, and for furnaces generally such as linings, flame channels, furnace piers, etc.

#### Availability

Bricks of both these groups have been available for some years in the United States. There, the improvements achieved in furnace efficiency by the first group, and the proved economy in terms of reduced furnace maintenance gained by the second group, have been firmly established.

Until quite recently, however, they have not been made in Britain, nor, for that matter, anywhere in Europe, and currency restrictions have prevented them from being freely imported from America.

Recently, however, with the encouragement of the Ministry of Supply, The Morgan Crucible Co. Ltd., have put into production bricks of both groups at the new Neston, Cheshire, factory of

TABLE 3.

*Furnace Conditions*

Operating temperatures, 2,400°F. (1,316°C.).  
 Single shift daily cycle (10 hours firing)—five-shift week.  
 Original structure: 13½ in. firebrick walls and roof.  
 Lightweight structure: 13½ in. M.I.28 walls and roof.  
 Furnace wall and roof area = 100 sq. ft.  
 Quantity of material required per 100 sq. ft. of 13½ in. thick wall = 1,600  
 9 in. × 4½ in. × 3 in. squares.

*Cost of Materials*

	£	s.	d.
Scottish firebrick at £25 per 1,000	40	0	0
M.I.28 at £114 per 1,000	182	8	0
∴ Additional cost of insulation	142	8	0

*Annual cost of fuel to heat and maintain walls at operating temperature (Fuel—*

	£	s.	d.
Town Gas at 11d. per Therm)	300	0	0
Scottish firebrick	94	0	0
M.I.28	206	0	0
∴ Reduction in annual fuel cost	63	12	0

*∴ Overall saving in first year's operation of furnace per 100*

sq. ft. of wall area

their wholly-owned subsidiary Morgan Refractories Ltd. In the first group, the range now being manufactured includes the M.I.28, M.I.26, and M.I.23, which will stand up to furnace, or interface, temperatures of 2,800°F., 2,600°F. and 2,300°F., respectively. In the second group, the range in production includes

M.R.1, with an alumina content of 43 per cent, and M.R.60, with an alumina content of 60 per cent. The latter has a very high resistance to thermal stresses, high stability at temperatures up to 1,600°C., much improved resistance to iron oxide slags and scales and good resistance to all fuel slags.

**POTTERY COURSE**

After the success of the first two pottery courses held by the Council of Industrial Design (Co.I.D.) for retailers and with continuing support from the trade, the Co.I.D. has decided to arrange a third course. This will be held from 20th to 24th September, at the Wedgwood Memorial College, Barlaston, Stoke-on-Trent.

Retailers should find this course most helpful, dealing as it does with various aspects of pottery manufacture and selling. Today new ways of living are creating a demand for fresh thought in the design of the articles we use in our homes. With this demand have come changes in the pottery industry and now designs, modern in shape and decoration, are being produced as well as those that have been traditionally accepted. It is of the greatest importance that retailers selling pottery should keep abreast of such developments.

During the course talks will be given by well-known manufacturers and authorities on pottery, who will discuss the history of pottery making, methods of manufacture of earthenware and fine china, the problems of design and display, and the retailer's responsibility.

Visits to factories in the neighbourhood

will play an important part in the programme, and at the College there will be an exhibition of tableware in current production, and some examples from overseas.

The inclusive charge per head for the course is £8 8s. 0d. Since accommodation is limited, applications should be made as soon as possible to the Retail Section, Council of Industrial Design, Tilbury House, Petty France, London, S.W.1.

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# Adherence of Porcelain Enamel to Steel

ONE of the first explanations advanced by scientists for the adherence of vitreous-base coats to steel was that of mechanical gripping. This hypothesis is based on the observation that when adherence is good, there is a rough interface between the coating and the metal, as shown in the sketch at Fig. 1. The coating penetrates into the cavities or undercuts in the metal surface and, when the coating hardens on cooling, the two materials are interlocked and thus mechanically bonded.

## Recent Evaluation of Adherence

While previous investigators have noted that rough interfaces are associated with good adherence, there has been no quantitative study of this relationship, probably because a method of evaluating adherence quantitatively has only recently become available. This method was used by American investigators of the National Bureau of Standards,<sup>1</sup> who came to the following conclusions:

1. A positive correlation was found between the adherence of a porcelain-enamel ground coat and the roughness of the interface.

2. In general, adherence correlated better with anchor points per centimetre than with the increase in interfacial area (interface ratio).

3. The method of metal preparation has a marked effect on the relation between roughness of interface and adherence of porcelain-enamel ground coats to enamelling iron. In general, better adherence was associated with enamels applied to pickled iron than to sandblasted iron for the same degree of roughness of interface.

4. Most of the roughness that was associated with good adherence between a porcelain-enamel ground coat and iron developed during the

firing process.

5. Roughness of interface is a necessary, but not a sufficient, condition for the development of good adherence between a porcelain-enamel ground coat and iron.

6. One or more factors other than roughness of interface also influence the adherence between a porcelain-enamel ground coat and iron.

## Nature of Tests

To find these conclusions investigations have been conducted in which porcelain-enamel ground coats were prepared and applied under conditions that gave various degrees of adherence between enamel and a low-carbon steel (enamelling iron). The variations in adherence were produced by (a) varying the amount of cobalt-oxide addition in the frit; (b) varying the type of metallic-oxide addition in the frit, keeping the amount constant at 0.8 weight per cent.; (c) varying the surface treatment of the metal before application of the enamel, by pickling, sandblasting, and polishing; and (d) varying the time of firing of the enamel containing 0.8 per cent. of cobalt oxide.

Metallographic sections were made, on which the roughness of interface was evaluated by counting the number of anchor points (undercuts) per centimetre of specimen length and also by measuring the length of the interface and expressing results as the ratio of this length to the length of a straight line parallel to the over-all direction of the interface.

One basic frit composition and one mill-batch formula were used for all of the enamels prepared in this study. The frit composition is given in Table I and the mill batch in Table II. Each frit, with the appropriate metallic-oxide addition, was batched, smelted and prepared as an enamel slip according to standard procedures. Table III lists the metallic oxides added to the base frit batch to produce the various frits.

<sup>1</sup> Richmond, J. C., Moore, D. G., Kirkpatrick, H. B., and Harrison, W. N., Nat. Advisory Committee for Aeronautics, Tech. Note 2934.



Fig. 1. Sketch ( $\times 1,000$ ) of metallographic section of porcelain-enamel ground coat containing 0.8 per cent. cobalt oxide applied to sandblasted enamelling iron, showing rough interface between enamel and iron. This specimen had excellent adherence

### Choice of Oxides

The oxides indicated in Table III were chosen for several reasons. Cobalt, nickel and manganese oxides are commonly used as adherence-promotion oxides in commercial ground coats although manganese oxide is of no value when used alone and of questionable value when used in combination with the other two oxides. Antimony and molybdenum

oxides are said to promote adherence to some extent. The other oxides were included because of the position of the metal in the electromotive-force series of the elements\* in relation to iron and cobalt. In this series  $\text{Cr}^{+++}$  is above  $\text{Fe}^{++}$  (which is considered the active iron ion at the enamel-metal interface);  $\text{Cd}^{++}$  is between  $\text{Fe}^{++}$  and  $\text{Co}^{++}$ ; and  $\text{As}^{+++}$  and  $\text{Cu}^{++}$  are considerably below  $\text{Co}^{++}$ .

TABLE I  
BASIC COMPOSITION OF FRITS USED FOR PREPARING VARIOUS GROUND COATS

(a) Batch Composition	Material	Parts by weight	(b) Computed oxide Composition	Oxide	Per cent. by weight
Potash feldspar	30.82		SiO <sub>2</sub>	51.0	
Borax (hydrated)	44.25		B <sub>2</sub> O <sub>3</sub>	16.1	
Flint	30.50		Al <sub>2</sub> O <sub>3</sub>	5.7	
Soda Ash	9.16		Na <sub>2</sub> O	15.4	
Soda nitre	5.15		K <sub>2</sub> O	3.5	
Fluorspar	8.30		CaF <sub>2</sub>	8.3	
	128.18				100.0

\* The electromotive force series of the elements was prepared from measurements of the potential developed between the element and an aqueous solution of the ion involved in which the ion was at unit activity (approximately one normal for most ions). Under these conditions the ions used in this study fall in the following order:  $\text{Mn}^{++}$ ,  $\text{Cr}^{+++}$ ,  $\text{Fe}^{++}$ ,  $\text{Cd}^{++}$ ,  $\text{Co}^{++}$ ,  $\text{Ni}^{++}$ ,  $\text{Mo}^{+++}$ ,  $\text{Sb}^{+++}$ ,  $\text{As}^{+++}$ , and  $\text{Cu}^{++}$ . It is known that molten glass acts as an electrolyte and that electrode potentials are developed in it, but the measurement of such potentials involves serious experimental difficulties. While the magnitude of the potentials may be considerably different, it is to be expected that the order of the elements will be about the same whether the electromotive force is developed in water or a glass, provided there are no complicating side reactions in the glass.

TABLE II  
Mill batch used for preparing ground-coat slips

(Milling time, 4.2 hr.; 50 ml. water plus three drops saturated  $\text{Na}_4\text{P}_2\text{O}_7$  added before removing slip from mill; fineness, 4 gm. on 200 mesh from 50 ml. of slip)

Material	Weight, gm.
Frit	1,000
Enameller's clay	60
Borax	10
Water	425

### Preparation and Application of Enamels

Twenty-gauge enamelling iron blanks, 4 in. by 4 in., were sheared to size and prepared for enamelling (a) by sandblasting; (b) by pickling, using standard procedures not including the nickel dip; and (c) by grinding and polishing.

The enamels were applied by dipping, and each slip was adjusted to give a fired enamel coating  $5 \pm 1$  mil thick. Specimens of all enamels were fired at  $1,575^\circ \text{ F}$ . for 4 min. except that a temperature of  $1,550^\circ \text{ F}$ . was used in a part of the investigations

where adherence was varied by changing firing time.

The adherence of specimens of each enamel prepared under each condition was evaluated in the test mentioned using seven specimens for each determination. The test evaluates the degree of adherence in terms of the amount of metal exposed by a standard deformation treatment, expressed as a percentage of the total deformed area. An adherence index of less than 50 by this test is usually considered so poor as to be commercially unacceptable. Although there is no standard classification of adherence indices, values of 50 to 75 were considered fair, 75 to 90 good, and 90 and above, excellent.

A metallographic section was made of each enamel having the adherence value nearest the average for the group, and evaluations of roughness of the interface were made on this section. For the first few specimens roughness was evaluated by examining the section microscopically and counting the number of anchor points per centimetre. Fig. 2 shows the criteria used in counting anchor points. These counts correlated well with adherence but the counting operation was very tedious since many fields had to be counted to obtain a statistically reliable mean value for each section.

TABLE III  
Coating identification and metallic oxides added to base frit batch.

Coating Designation	Oxide Added	Parts by Weight <sup>1</sup>
I-1	—	—
A	$\text{Co}_3\text{O}_4$	.01
B	$\text{Co}_3\text{O}_4$	.1
C	$\text{Co}_3\text{O}_4$	.2
D	$\text{Co}_3\text{O}_4$	.4
E	$\text{Co}_3\text{O}_4$	.8
F	$\text{Co}_3\text{O}_4$	1.6
G	$\text{Co}_3\text{O}_4$	3.2
H	$\text{Co}_3\text{O}_4$	6.4
J	$\text{Sb}_2\text{O}_3$	.8
K	$\text{As}_2\text{O}_3$	.8
L	$\text{CdO}$	.8
M	$\text{Cr}_2\text{O}_3$	.8
N	$\text{CuO}$	.8
O	$\text{MnO}_2$	.8
P	$\text{MoO}_3$	.8
Q	$\text{NiO}$	.8

<sup>1</sup>Added to quantity of raw batch required to make 100 parts of frit

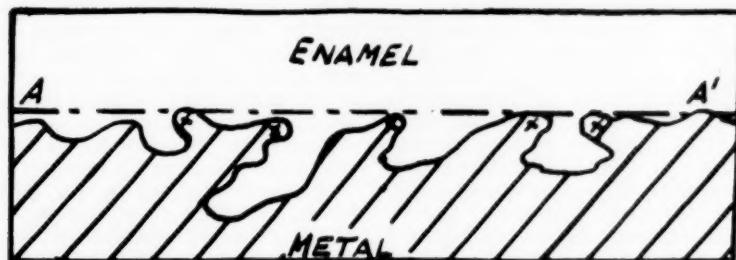


Fig. 2. Schematic section of enamel-metal interface, showing methods used to evaluate roughness. Anchor points (undercuts) indicated by  $X$ , were counted and expressed as number per centimetre of specimen. In the second method, length of line representing interface was measured with a map measure and expressed as a ratio of length of straight line  $A'$ , parallel to interface

TABLE IV

Adherence, anchor points per centimetre, and interface ratio for coatings with various cobalt contents

Coating designation	Cobalt content per cent.	Adherence Index	Error <sup>1</sup>	Anchor points no./cm.	Error <sup>1</sup>	Interface ratio	Error <sup>1</sup>
<i>Applied to pickled metal</i>							
I-I	0	5.68	3.25	63	43	1.11	0.020
A	.01	2.64	1.52	8	11	1.07	.012
B	.1	4.90	1.86	228	68	1.24	.032
C	.2	7.60	2.75	304	79	1.27	.032
D	.4	62.8	6.00	583	126	1.41	.060
E	.8	93.9	1.86	729	115	1.48	.071
F	1.6	91.6	2.09	898	134	1.59	.061
G	3.2	74.4	4.09	839	118	1.54	.061
H	6.4	65.3	2.89	1012	135	1.68	.074
<i>Applied to sandblasted metal</i>							
I-I	0	1.80	1.06	173	49	1.25	0.033
A	.01	5.62	2.00	319	83	1.24	.047
B	.1	14.7	4.05	323	80	1.31	.059
C	.2	42.4	10.27	945	128	1.69	.095
D	.4	58.6	6.30	1028	126	1.62	.095
E	.8	90.7	2.67	1052	175	1.85	.132
F	1.6	84.8	4.06	1347	156	1.92	.139
G	3.2	84.3	2.52	1701	208	1.90	.091
H	6.4	77.6	2.91	1233	148	1.71	.105
<i>Applied to polished metal</i>							
E	0.8	90.5	4.80	833	145	1.36	0.051
H	6.4	61.7	4.33	933	139	1.52	.064

<sup>1</sup>95 per cent. confidence error for average value reported in preceding column

## Photomicrographic Reproduction

In later experiments, photomicrographs at 1,000 diameters were taken of twenty areas selected on each section. The negatives of these photomicrographs were then projected on to a sheet of paper to produce a magnification of 10,000 diameter and a tracing was made with a soft pencil of the enamel-metal interface. Such a tracing is shown Fig. 2. Roughness was evaluated by counting the number of anchor points and converting this value to the number per centimetre length. An anchor point was taken as a definite undercut in the metal. An undercut overshadowed by another undercut was not counted. In Fig. 2 the locations to be counted as undercuts are indicated by crosses. Vertical lines, normal to the interface were used to determine whether or not a definite undercut occurred. As a

second method of evaluating roughness the length of the line representing the interface was determined with a map measure. Results were expressed as the ratio of the interface length to the length of a straight line parallel to the interface (line AA' Fig. 2). This value was called the "interface ratio."

If adherence is due to the "keying-in" action of the rough interface, the best correlation between adherence and roughness of interface should be obtained when roughness is evaluated in terms of anchor points per centimetre. On the other hand, if adherence is due to a chemical bond between enamel and metal, the bond strength would be expected to be a function of area of contact, and better correlation should be obtained between adherence and roughness when roughness is evaluated in terms of the interface ratio.

TABLE V

Adherence index, anchor points per centimetre, and interface ratio for coatings containing 0.8 per cent. of various metallic oxides

Coating designation	Metal-oxide addition	Adher-ence Index	Error <sup>1</sup>	Anchor points no./cm.	Error <sup>1</sup>	Inter-face ratio	Error <sup>1</sup>
<i>Applied to pickled metal</i>							
E	Co <sub>3</sub> O <sub>4</sub>	93.9	1.86	729	115	1.48	0.071
J	Sb <sub>2</sub> O <sub>3</sub>	62.5	8.27	603	117	1.43	0.061
K	As <sub>2</sub> O <sub>3</sub>	3.33	1.14	91	50	1.13	0.051
L	CdO	2.78	.76	87	63	1.14	0.035
M	Cr <sub>2</sub> O <sub>3</sub>	.89	.32	16	19	1.07	0.013
N	CuO	2.90	2.14	106	54	1.18	0.039
O	MnO <sub>2</sub>	1.80	1.50	35	31	1.08	0.018
P	MoO <sub>3</sub>	1.89	1.14	8	11	1.09	0.012
Q	NiO	76.3	6.82	556	126	1.36	0.053
<i>Applied to sandblasted metal</i>							
E	Co <sub>3</sub> O <sub>4</sub>	90.7	2.67	729	115	1.48	0.071
J	Sb <sub>2</sub> O <sub>3</sub>	14.3	3.04	528	87	1.44	0.070
K	As <sub>2</sub> O <sub>3</sub>	15.2	3.95	520	106	1.53	0.100
L	CdO	18.6	2.48	394	79	1.46	0.112
M	Cr <sub>2</sub> O <sub>3</sub>	7.9	1.61	567	124	1.48	0.110
N	CuO	7.0	1.60	693	110	1.64	0.119
O	MnO <sub>2</sub>	4.2	3.95	378	87	1.40	0.083
P	MoO <sub>3</sub>	7.7	3.41	614	101	1.60	0.111
Q	NiO	41.7	11.35	772	95	1.67	0.100

<sup>1</sup>95 per cent. confidence error for average value reported in preceding column

TABLE VI

Adherence index, anchor points per centimetre, and interface ratio for enamel E (0.8 per cent. cobalt) fired various times at 1,550° F.

Firing time, min.	Adherence Index	Error <sup>1</sup>	Anchor points, no./cm.	Error <sup>1</sup>	Interface ratio	Error <sup>1</sup>
<i>Applied to pickled metal</i>						
2	40.2	28.4	657	109	1.37	0.036
4	97.5	2.21	717	123	1.44	0.051
6	96.9	2.28	740	110	1.50	0.039
8	92.1	2.93	732	99	1.48	0.040
12	88.3	3.50	744	106	1.46	0.053
18	84.2	4.48	763	107	1.50	0.047
<i>Applied to sandblasted metal</i>						
2	48.7	11.2	787	122	1.64	0.091
4	91.1	3.0	1091	122	1.91	0.105
6	91.3	3.2	886	135	1.66	0.096
8	89.7	3.4	953	124	1.73	0.082
12	85.3	4.6	847	131	1.67	0.079
18	78.4	3.1	870	154	1.63	0.090

<sup>1</sup>95 per cent. confidence error for average value reported in preceding column

## Results

Preliminary data on the adherence, anchor points per centimetre, and interface ratio for enamels A to H can be plotted as a function of cobalt-oxide content. It will then be seen that the two measures of interfacial roughness correlate well with adherence.

The data on adherence, anchor points per centimetre, and interface ratio for the various specimens are presented in Tables IV, V, and VI.

Where adherence was taken as a function of the cobalt-oxide content of the enamel frit for enamels applied to polished, pickled, and sandblasted metal it was found that in each case, maximum adherence was obtained with enamel E (0.8 per cent. cobalt oxide). Type of metal preparation did not significantly affect the adherence of this metal but where the adherence was excellent (90 per cent. +) the enamels adhere better to pickled metal, and, where the adherence is poor, the enamels generally adhere best to sandblasted metal. Better adherence was obtained on pickled or

sandblasted metal than on polished metal, especially for enamel H (6.4 per cent. cobalt oxide).

Where adherence was taken as a function of firing time it was found that adherence went through a maximum at some time between 4 min. and 6 min. Except for specimens fired for 2 min. (on which adherence was poor) better adherence was obtained in every case on pickled metal than on sandblasted metal. All specimens in this time test were coated with enamel E, found to give the maximum adherence.

In tests on enamels containing the various metallic oxides applied to both pickled and sandblasted iron, the effect of metal preparation was the same as before: if adherence is poor, the enamel adheres better to sandblasted iron; if adherence is good the enamel adheres better to pickled iron. No adequate explanation was found as to why the antimony bearing enamel adhered so much better to pickled iron than to sandblasted iron.

TABLE VII  
Correlations between adherence and roughness of interface

Variable	Metal Preparation	No.	Correlation Coefficients	
			Adherence Against	
			Anchor points/cm.	Interface ratio
All Cobalt content	All	48	0.786	0.662
	Pickled	9	.904	.873
	Sandblasted	9	.926	.964
	Pickled	9	.986	.961
	Sandblasted	9	.844	.816
	Pickled	6	.806	.816
Metal oxide content	Sandblasted	6	.663	.457
Time of firing				

#### Adherence Factors

Correlation coefficients were computed for the relation between (i) adherence and anchor points per centimetre and (ii) adherence and interface ratio for each group of specimens, with the results indicated in Table VII. With but two exceptions, where the differences are slight, adherence correlated better with anchor points per centimetre than with interface ratio. This finding indicates that the keying-in action of the rough surface is probably more important than the effect of the increased area of contact between enamel and metal.

Two observations made indicate that one or more factors other than

roughness of interface also affect adherence. These were that good adherence was in all cases associated with value of roughness above 500 anchor points per centimetre while values of roughness up to 1,000 anchor points per centimetre were sometimes associated with poor adherence.

Under optimum conditions no significant difference was found between the adherence obtained on polished metal, which was completely smooth before coating, and that obtained on sandblasted metal, which was initially fairly rough. This indicates that the roughness associated with good adherence must have been developed during the firing process.



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# Special Glass Making

## An American Development

*This report describes experiments by an American firm to produce, on a pilot plant scale, a low dielectric constant, low loss tangent glass. This was to be formed into glass marbles for drawing into continuous glass fibres, glass yarns and cloths. A special chemical finish was to be applied to the resulting cloth.*

RECENTLY the American Government made a contract with Glass Fibres Inc., U.S.A., for the development of a glass composition (see Table 1) which gave a dielectric constant of 3.87 at 10,000 megacycles and a loss tangent of 0.001. It was essentially a low alkali borosilicate having a high resistance to attack by moisture. Fibres were drawn from this glass, termed glass 6-6-4, and laminates prepared. The whole process included batch composition, furnace design, melting procedure, and forming apparatus.

### Equipment

The melting chamber of the furnace has an area of 12 sq. ft. and its dimensions are 9 in. deep by 2 ft. wide by 6 ft. long. Seven burner openings are provided for on each side of the tank. An opening for a screw-type batch feeder is installed in the rear end wall of the combustion chamber. The tank combustion stack is built into the crown at the rear end of the tank adjacent to the rear end wall.

A 5 in. feeder spout receives the glass from the melting chamber of the tank after it has passed under a skimmer block. Six burner openings are provided for around the feeder spout.

A 2½ in. by 27 in. long tapered point plunger is suspended over the orifice in the feeder spout and up and down movement for control of the volume of glass delivered is provided for.

Natural gas is used as a fuel. The combustion equipment consists of a 400 cfm. blower and related equipment. The gas flow through the system progresses from a 2 in. gas supply line through a first stage regulator which reduces the supply line pressure to  $\frac{1}{2}$  lb. The gas then passes through a safety valve, an atmospheric regulator, to a mixer. The combustion air is supplied by a 400 cfm. blower and the blower air passes through

a butterfly valve and into the mixer. At this point the gas and air unite and are mixed. The combustion mixture then passes into the furnace manifold and on through each of the fourteen burners in the melter and the six burners in the feeder bowl.

The marble forming machine consists of a glass shear mechanism assembly mounted on the head frame of the machine, two gob chutes and positioning cups, and two pairs of marble forming, spiral-grooved, variable-speed driven rolls.

The shear mechanism consists of a cup and cup plate, a moving shear plate and a bottom shear plate. The cup has a circular carboloy cutter inserted and brazed into position in the bottom of the cup. The moving shear plate contains two removable circular carboloy cutters set into two bored holes in the plate. The carboloy cutters are set upon height-adjusting threaded rings and these rings are locked into place by a second threaded ring containing set screws. The moving shear plate is cooled by circulating water through the plate between the inserted carboloy cutters. The bottom plate is stationary and also contains two bored holes. Two aligning cups are set in the bored holes on the underside of the bottom plate. The bottom plate is water cooled by circulating water through the plate between the two bored holes.

Directly below the aligning cups in the bottom plate are mounted two chutes; these are held in position by an adjustable bracket which bolts the head frame of the marble machine.

Above the marble forming rolls and under the gob chutes are located the positioning cups. These are adjustable and are held in position by brackets which are bolted to the head frame of the marble machine.

The marble forming, spiral-grooved, variable-speed, driven rolls are mounted on the main frame of the marble machine. The inside rolls of each pair are fixed in a manner which prevents lateral and longitudinal movement of the rolls. The outer rolls of each pair are mounted in a manner that allows for manual lateral and longitudinal movement.

The shafts of each roll contain a gear

## CERAMICS

at the driven end of the machine and are so geared that as one looks from the driven end of the machine towards the head end, the outer rolls turn clockwise and the inner rolls counter-clockwise.

A motor-driven, variable-speed drive unit supplies the moving force for the marble machine. The machine has four wheels set upon a track for movement. An in-and-out lever and linkage furnish the necessary force to provide manual movement of the machine from a position away from the glass stream to a position directly under the stream.

The batch feeder consists of a motor-driven screw, a batch hopper and tube. Power to turn the screw is furnished by a motor and gearbox driven by a pulley and V-belt unit. The screw is contained inside a water-cooled tube. Above the screw and forming a part of the tube is the hopper on the outer side of which is mounted a vibrator.

A 24 in. laboratory mixer was used to mix the 6-6-4 batch. It has a capacity  $\frac{1}{4}$  c. ft. at 100 lb. c. ft. The mixer processes the batch through the action of cast-iron wheels called mullers and ploughs which serve to move the batch to the centre and then outward within the mixer pan. The discharge of the mixer is located in the bottom of the pan.

The laboratory mixer used has a 2 ft. diameter pan and a 10 in. depth. The vertical shaft turns 40 r.p.m. and powers two mullers which weigh 100 lb. each.

### Glass Making

Glass 6-6-4 had a calculated batch composition as given in Table 1, in which the chemical analysis is also given.

TABLE 1.

Silicon dioxide (SiO <sub>2</sub> )	74.5	74.00
Iron and aluminium oxide (R <sub>2</sub> O <sub>3</sub> )	—	0.76
Calcium oxide (CaO)	0.5	0.61
Magnesium oxide (MgO)	—	0.13
Sodium oxide (Na <sub>2</sub> O)	1.0	1.12
Potassium oxide (K <sub>2</sub> O)	1.5	1.18
Lithium oxide (Li <sub>2</sub> O)	0.5	0.22
Boric oxide (B <sub>2</sub> O <sub>3</sub> )	22.0	22.16
100.0	100.00	

The batch used, consisted of materials in the proportions set out in Table 2.

TABLE 2.

Sand*	76.70
Anhydrous borax	3.30
Boric acid	39.50
Potassium carbonate	2.60
Lithium carbonate	1.25

\* The sand had the following analysis:

Silicon dioxide (SiO <sub>2</sub> )	97.12
Iron and aluminium oxide (R <sub>2</sub> O <sub>3</sub> )	5.59
Magnesium and calcium oxide (RO)	1.14
Ign. Loss	1.10

The sand furnished all of the silica and the excess of alkaline earths (magnesium and calcium oxides), and R<sub>2</sub>O<sub>3</sub> (oxides of iron and aluminium).

Anhydrous borax, which contained 68.85 per cent. boric oxide and 30.48 per cent. sodium oxide, furnished all of the sodium oxide in the batch as well as a portion of the boric oxide.

The balance of the boric oxide in the batch was furnished by boric acid which contained 56.0 per cent. boric oxide and 44.0 per cent. water. A 12 per cent. addition of boric acid above the calculated was made to compensate for volatilisation losses.

The potassium oxide in the glass had an analysis as follows:

Potassium carbonate (K <sub>2</sub> CO <sub>3</sub> )	84.22
Potassium bicarbonate (KHCO <sub>3</sub> )	Nil
Potassium hydroxide (KOH)	0.06
Potassium chloride (KCl)	0.034
Potassium sulphate (K <sub>2</sub> SO <sub>4</sub> )	0.13
P.P.M. Fe	4.00

The balance was water. The various potassium salts were calculated to yield a total of 57.5 per cent. K<sub>2</sub>O.

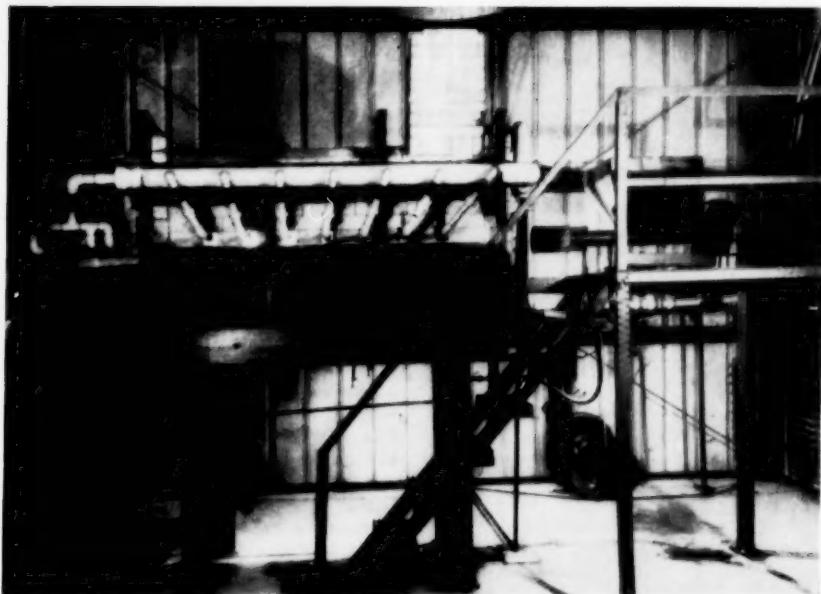
Lithium oxide was supplied to the glass by lithium carbonate of the following analysis:

	% approx.
Lithium carbonate	99.200
Other alkalis as oxides	0.240
Sulphate	0.350
Calcium oxide	0.020
Ferric oxide	0.002
Chlorine	0.003
Heavy metals	0.001
Water	0.010

In order to conform to the capacity of the mixer, the following 6-6-4 glass batch weights were used:

Sand	25.56 lb.
Anhydrous borax	1.10 lb.
Boric acid	13.16 lb.
Potassium carbonate	0.86 lb.
Lithium carbonate	0.42 lb.
Total weight	41.10 lb.

After weighing, the materials were placed in the mixer pan and mixed for 10 minutes. Initially an attempt was made to feed the batch into the furnace with a screw-type batch feeder similar in design to that used throughout the glass industry. The batch did not lend itself to this method of feeding due to



Part of the American plant producing, on a small scale, glass for special purposes

the fact that it "set up" shortly after being mixed. Any attempt to break it up and feed it into the furnace with the screw-type feeder failed because it would harden and bridge over the screw.

It was decided to fill the furnace by hand through the furnace stack. The batch was placed in 2 lb. paper sacks as it was mixed and set aside until the feeding cycle began. Immediately after each day's run of marble production the feeding cycle was started and continued at the rate of 10 lb. of batch every 10 minutes until normal glass level was restored. Between each 10 minute cycle the cullet produced at the marble machine was fed into the furnace through the stack.

Since the manufacture of 6-6-4 glass was to be a commercial operation, the rate of pull, temperatures required, time cycle, and end composition were discussed and plans laid to fulfill this requirement. It was decided that a 12 sq. ft. furnace operating at 2,750°F. would melt the specified 400 lb. of glass per day. It was also decided that an addition of 12 per cent.  $B_2O_3$  in excess of that required by composition would suffice for volatilisation and give the desired composition.

It was found necessary to operate the 400 cfm. combustion blower at full

capacity to attain the required temperature to melt the batch and hold the glass temperature in the bowl high enough to form the glass. The melter temperature held on the furnace was 2,750°F.

The cycle of daily operation was as follows. Four hours was spent in running glass from the furnace and forming marbles. The next eight hours was spent in feeding batch and cullet into the furnace. The following 12 hours gave the batch time to melt and refine to the degree felt necessary for the subsequent fibre-forming operation.

#### Marble Forming

The forming of the 6-6-4 glass into marbles initially presented a problem in that the temperature of the glass was higher than previously experienced. As a result, the shear mechanism kept plugging up thus causing interruption of the marble forming process. This was due to the hot glass sticking to the sides of the shear cup which prevented the glass from passing through the shearing process and on to the marble forming rolls. To overcome this difficulty a water-cooled shear cup was installed on the shear assembly and the shearing of the glass proceeded smoothly. The

(Continued on page 275.)

# HOLLAND WARE

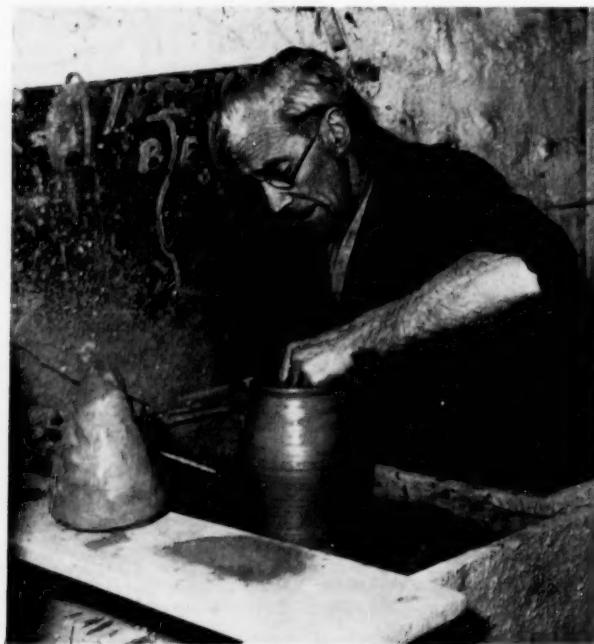
*from a Cottage Pottery*

READERS of CERAMICS will be interested to learn that hand-thrown ware made in a Clevedon, Somerset, cottage pottery is finding a ready sale in many overseas markets, and that at home, demand is greater than the supply. The same is true of many family potteries in the West of England where skilled hands carry on a tradition handed down for centuries.

Mr. W. Fishley Holland, the owner and founder of the Clevedon Pottery, came to Somerset 30 years ago from North Devon where his antecedents had been potters since 1771. The family craft is still carried on at Fremington from where on his brother's farm Mr. Holland gets 10 tons of red clay every year. He has experimented with Clevedon river clay, but finds it too coarse for Holland Ware, which has gained a wide reputation for quality and workmanship.

He employs the old familiar method of handling clay. After being washed and cleaned in a claypit, it is put into vats and the surface water syphoned off before being placed through a pug mill for pressing and cutting into 40 lb. slabs. Throwing his pots with ease and economy of movement natural to a man who comes of six generations of potters, he is proud to relate that at a very early age he could throw 120 pots of  $3\frac{1}{4}$  in. diameter in an hour. He still uses a kick wheel as does his son George who assists him, for both are able to "concentrate better" when working with the old type. Only one other potter is employed, besides a student whom Mr. Holland wants to encourage in learning the art of colour and design.

A born artist-craftsman Mr. Holland adheres steadfastly to the old methods, and has just built a new



Mr. Holland  
throwing a pot  
in his cottage pottery

coal fired kiln to satisfy his liking for the traditional. But the need for speeding up production to meet the ever-increasing demand for hand-made pottery has caused him to augment this by two new electric kilns each of 12 cu. ft. firing up to 1,250° C. which will raise the 20,000-pieces-a-year output considerably. Mr. Holland is determined not to increase his prices despite the higher cost of production.

The pottery remains essentially a family business, for this shrewd artist in clay is convinced that there is an unlimited demand for colourful, hand-made individualistic pottery. He believes that there is not a tremendous demand for what is called contemporary pottery and that people like conventional designs. There is nowadays a preference for good colour and tonings; muted shades of grey and pale brown are not popular. Mr Holland says that he works on the old Devonshire tradition of 200 years ago, as opposed to the semi-Staffordshire style which is what most of the young potters of today are using. Green in all shades is the most popular colour, as it has been for a century past, while cream tints and pastel and turquoise are well liked.

Most of the glazes used at Clevedon are made from a recipe handed down from former generations, and sometimes the biscuit ware emerges from the kiln with a lustre that astonishes even Mr. Holland by its sheer beauty. Colour is the keynote of Holland's popularity. If Edmund Fishley, the founder of the family, made his fame mainly by being the first potter in England to apply colour to humble kitchen ware, today his descendants owe their high standing to the exquisite glazes with which they colour their products.

Holland's could sell the whole of their four-man output of domestic and decorative pottery to countless visitors from all parts of the country, but the requirements of valued retail customers have to be met as well as a growing overseas market, which includes the United States and South America, South Africa and the Rhodesias, while a sample order of lamp bases has just been sent to New Zealand.

Although Mr. Holland has concentrated on traditional West of England designs, he also made time to adapt



The potter stands proudly beside his handiwork

native shapes from Hungary, Bavaria and Czechoslovakia, and has occasionally made copies of ancient Egyptian pottery.

A striking hand-thrown Holland dish with Old English feathering and thumbed edge was photographed for inclusion in the Festival of Britain Exhibition catalogue, and in his tiny showroom there are also samples of Sgraffito on old Bideford beer jugs—a process for which the Fremington founder was justly famous—and replicas of Roman and ancient British feeding bottles made from clay found by Mr. Holland in the Mendips, where lead was mined by the Romans.

Active in the craft's interests, Mr. Holland finds time to be a member of the committee of craft potters formed in conjunction with the Crafts Centre of Great Britain, the Somerset Guild of Craftsmen and the Red Rose Guild of Art Workers.

## New H.Q. for Glass Manufacturers' Federation

TO meet the need for more suitable headquarters commensurate with the importance of the industry the Glass Manufacturers' Federation has acquired 19 Portland Place as a location for its meetings, staff and records and as a base from which collective publicity will be undertaken.

For the internal decoration of the ground floor and first floor rooms of the new premises, which is a late 18th-century house, the Royal College of Art was commissioned to prepare a scheme in which it was decided that the existing character of the rooms would be preserved in the main, but use made of furniture of contemporary design. The Royal College of Art invited Margaret Casson A.R.I.B.A. to undertake the work on its behalf and where possible to use the services and talents of students of the School of Interior Design, or other appropriate department as part of their day to day training.

The ground floor consists of an entrance hall and inquiry desk, a room for the occasional exhibition of glass and allied manufacturers, a members' sitting room and small library. The second floor contains two conference rooms to seat twenty-two and ten respectively.

A view of the well-appointed and luxurious rear committee room



In the showroom is an exhibition illustrating the story of glass

The basement of the new headquarters has been converted by Lionel S. Rider A.R.I.B.A. and Cyril Weeden M.S.I.A. into a permanent exhibition showing the history, raw materials, processes and products of British glass-making. It is believed to be the only exhibition of its kind in Europe.

As well as demonstrating up-to-date methods of glass-making, working with glass and decorating glass, the exhibition shows how glass is used by industry as a component part of other products. There is also a showroom where a representative display of the products of the industry are assembled.

Other features of the exhibition are a balcony panelled with figured sheet glass, which will be changed occasionally to show the variety of patterns available in this product; a valarium ceiling made from woven glass fibre yarn; and a corridor with a glazed screen in figured glasses and glazed ceiling, the last panel showing prefabricated sheet glass with glass fibre.

**SPECIAL GLASS MAKING.—(Continued)**  
*from page 271.)*

bowl temperature during the manufacture of the 6-6-4 glass was held at 2,780°F. and the optical temperature of the glass stream was 2,360°F.

The speed of the forming operation which gave best results was 160 cuts per minute. It was found that the 6-6-4 glass formed in much the same manner as that of other glasses.

**Glass Testing**

The glass marbles made in the experimental furnace were tested in a control laboratory. The tests given it were (1) a comparative viscosity test or flow test, and (2) a durability test.

In the flow test the glass is melted in a platinum pot having a single tip in the bottom. After a temperature equilibrium is reached, a fibre is drawn on a revolving tube for a measured interval. This procedure is repeated at several

temperatures. The weight of fibre drawn is plotted against temperature. If the temperature interval does not cover too wide a span the points fall fairly close to a straight line. A comparison of this line with a standard gives an indication of the "hardness" of the glass. In the case of glass 6-6-4 the indications were that a temperature, at least 300°F. higher than that usually employed in the plant, would be necessary.

The chemical durability of the glass was measured by leaching a 10 gram. sample of the glass for 4 hours in distilled water held at 176°F. The glass sample was prepared by crushing and screening through a 40 mesh sieve and on a 50 mesh sieve. The sized fraction was washed with distilled water and methyl alcohol. The amount of attack was determined by titrating the extracted alkali with 0.02 normal sulphuric acid using methyl red as an indicator. The results were expressed per cent. sodium oxide.

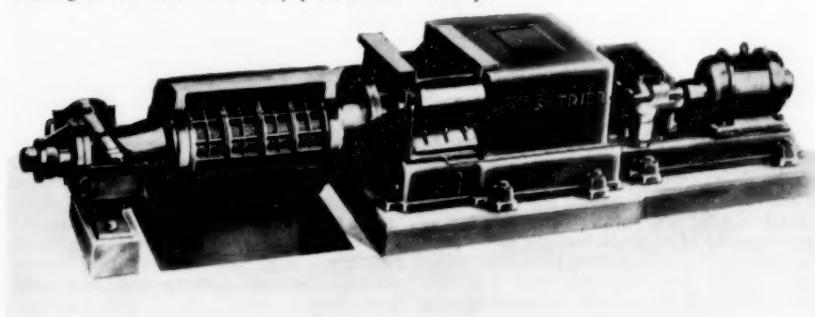
## A NEW CLAY PURIFIER

MANY clays with excellent qualities cannot be employed for the manufacture of high-grade tile and clay ware owing to the presence of impurities in the form of lime, rocks, coal, etc., which the usual preparation methods do not remove. For instance, if the percentage of lime present is large, the finest working up by means of runner mills or crushers will not eliminate its detrimental effects. Neither will these machines deal effectively with particles of coal, roots, rock, etc., and their undesirable presence can still be detected after the baking process.

The purpose of the clay purifier shown in the illustration, which was exhibited at the recent Hanover Fair, is to eliminate the impurities mentioned above, at the same time mixing the clay so that it ultimately leaves the machine as a truly homogeneous mass. The clay purifier de-

scribed has a solid bed equipped with charge trough and feed roll. The sieve body consists of removable sieve frames and steel sieves. The punch hole dia. depending upon the nature of the raw material being treated and degree of preparation required, may range from  $\frac{1}{8}$  to  $\frac{1}{2}$  in. A specially designed worm presses the clay through the perforations and the material leaves the purifier in thin homogeneous lines. The impurities are forced to a front collecting head and discharged through side nozzles. The machine is equipped with a forged steel worm shaft and has renewable liner plates of wear resisting steel. All gears constituting the drive are enclosed in a dust-tight oil bath. The drive may be direct or through reduction gears using an electrical motor or by means of belt and clutch.

This new clay purifier is made by the Laeis-Werke A. G. Trier/Mosel, Germany.



A new German clay purifier

# Researches on Screening Sticky Slip

IMPROVED types of vibrating screens have recently been developed to screen off sticky slip in a number of modern ceramic mills, in place of the beater and polygon screens which were formerly adopted. Earlier forms of vibrating screens were of the plan sifting variety which received their impulses from a small crank drive. This operated a striker which shook the frame with 3,000 blows per minute, and the crank drives were accordingly subject to an appreciable amount of wear.

Although the crank drives were later replaced by what are termed out-of-balance drives or magnets, a disadvantage remained with this plan sifting type of unit. The screens soon became clogged, and their efficiency diminished as the residues collected on them accumulated to an extent dependent upon the proportion of material handled. This meant that the outfit had to be stopped, and the screen frame removed for cleaning purposes. These accumulated residues acted as a burden on the screens, which were frequently very thin, forcing them downwards and rendering them slack, apart from the foregoing interruptions. The tight stretching of the gauze exerts a considerable influence on the effectiveness of a vibrating screen, and as the residues usually comprise sharp, frequently splinter-like grains, the high speed of vibration will naturally tend to impair this fine gauze very rapidly, and usually at one particular section.

#### Attempts to solve problem

Amongst attempts at solving this problem, and producing an ideal screening machine, the liquid has been set into vibration inside the screen frame instead of the screen frame itself, and a disc dipped into the liquid is caused to vibrate by means of a magnet. The vibrations are transferred to the screen at right angles to the plane of the screen, but it was not possible to eliminate the wear on the gauze, although the screening efficiency was otherwise outstanding. Because the vibrations acting at right angles to the axis of the screen represent an appreciable load on the screen, besides the screening residues, screening efficiency is diminished as the screen soon becomes slack. This research led to a further development in the screen for continuous removal of residues, and which is done using a sloping, vibrating screening sur-

face, which causes the screened material to drop downwards. On the other hand, the residues are made to slide down over the inclined screening surface, but these unfortunately place a load on the fine gauze, and tend to damage it, and hence this attempt at improvement had to be abandoned.

Only a brief reference can at present be made to research which is in progress using a screen made up of segments, wherein compressed-air is applied against the fine gauze surface to facilitate removal of residues. A rotary worm-shaped brush is caused to lightly rotate over the surface while this pressure is applied, with the object of eliminating the need for stoppages for cleaning purposes. Care has again to be exercised that such action does not in any way cause a slackening of the screen, otherwise wear would soon become apparent, and necessitate replacement.

#### Improved Screening Arrangements

One of the latest developments is a form of screen comprising a five-sided screening pot, four sides of which are provided with windows upon which the screen frames with the screen netting are fitted, while the fifth one has an unbalanced disc with ball bearings.

By means of a specially designed rubber sleeve, this pot is flexibly attached to a funnel. The funnel in turn is fixed to a container by means of screws, and upon it an electric motor is mounted in the vertical position, and which continuously runs with a speed of 3,000 r.p.m. The flexibly suspended screening pot is caused to vibrate in an elliptical path by the rotation of the unbalanced shaft. Through the funnel mentioned, the material is filled into the screening pot, and rises in it to a certain level, while, whereas the heavier residues drop to the bottom, the finely screened material leaves through the screen windows. In order to pour off the residues, a sludge tray is provided on the pot bottom, which can be removed in a single operation during the screening process. There are no interruptions, as the screen continues to run while the tray is being emptied. As the residues drop to the bottom and do not come into contact with the screen at all, the fine netting can never be destroyed.

With the plan sifting type of screen, vibrations all run parallel to the screen-

ing surface, or, in the instance of the immersed disc, they run at right angles to this surface. With this improved vertical screen, vibrations run both in the direction of the gauze, and also at right angles to it, because of the special arrangement of the unbalanced disc, and result in a very high screening effect. Instead of a large screen which is all in one piece, four separate screen fields are used, and any of which may be replaced should a fault develop, but not the entire unit. In spite of the high degree of efficiency attained, the amount of netting required is accordingly correspondingly low.

As the result of an ingenious clamping device used, when the screen netting does have to be replaced, this is carried out

rapidly, and the screen is simply placed against the window, and compressed by a frame, while the tighter the frame is pressed, the tighter will the screen be stretched itself. Without unduly entering into figures, the wet drum for fine grinding and intense mixing has a diameter of 55 in., the double-acting pump for transporting the slip a capacity up to 2,400 gal. per hour, the associated dry pug mill for grinding hard and medium-hard raw materials up to 11,000 lb. per hour, and the vacuum bar press for de-airing and homogenising fine ceramic masses 5 tons per hour. Fine screens have meshes upwards of 10,000 per sq. in., and one of the special screens used for research purposes is claimed to have 60,000 meshes per sq. in.

## ANCIENT AND MODERN

The new Wedgwood

Ronson lighter



A PARTICULAR concern of the "enlightened industrialist" of the eighteenth century was to blend functionalism with beauty. Though Wedgwood developed jasper principally as a decorative body, he ensured that its qualities gave it infinite practical application. In 1787 a Wedgwood advertisement offers "in jasper of two colours adapted to Argand's patent lamp" a new style of mechanical light. Yet Wedgwood entrusted the design and decoration of such utilitarian items to artist-craftsmen like John Flaxman and William Hackwood. Wedgwood's inventiveness in respect of lamps of all kinds caused him to develop a remarkable range of candle-vases, candlesticks and desk lamps for all purposes—all of them made in the blue and white jasper body.

Josiah Wedgwood would certainly have approved of any application of his jasper to a practical purpose. The association between Wedgwood and Matthew Boulton, the steel master, which produced so many beautiful combinations of jasper and cut steel, is brought to mind by the contemporary example of a similar association between the firms of Wedgwood and Ronson. Following the very successful Ronson table lighter in Wedgwood jasper celebrating the Coronation, there are now two new models each with jasper bases produced at the Wedgwood factory. These contemporary lighters are an interesting attempt to combine an entirely modern invention with an eighteenth-century ceramic without loss of the essential qualities of either. Josiah Wedgwood invented the jasper body for just such an application.

## BOOK REVIEWS

**Modern Ceramic Technique, by N. V. Raghunath, Bangalore Printing and Publishing Co. Ltd., Bangalore, India. Rs. 3/8.**

The full title of this small volume of sixty-five pages is "Modern Ceramic Technique Applicable to Indian Industries and Other Industrial Papers," and the author is the general manager of the Government Porcelain Factory at Bangalore, India. In his preface the author states that he will be only too glad if this small book helps in revitalising the Indian ceramic industry.

The book is actually a collection of essays. The first surveys the raw materials available in India for manufacturing high-tension insulators and details the machinery required for a factory to produce 2,000 tons of high-tension porcelain a year. It is estimated that there should be a return of 18 per cent. on the capital invested. The author thinks it might be possible in time to export surplus to Australia, South Africa, and Egypt. It might be well to comment here that Australia and South Africa are developing their own ceramic industries, and possibly share the hope that they too one day may be able to export surplus insulators.

The second chapter deals with Research and Development. The research institutes of the United States are given most of the space of this chapter, and there is a brief mention of the Silicate Research Institute in Germany. The fundamental work in developing ceramics in Great Britain and France is ignored. The author considers that one research centre in India is insufficient and hopes that the advent of the National Government in India will give a fillip to industrial research and a "new renaissance will begin in this country."

Chapter three is devoted to assessing the need for the manufacture of spark plugs in India. The present demand is estimated at 1½ million plugs each year. It is considered that these could be made from Indian kyanite, importing the special wire needed for the electrodes.

Chapter four is headed "Trends in Ceramic Industry." It surveys very briefly some of the features of present American production and two pages are devoted to tabulating the merits of the various types of tunnel kilns. The author hopes that these methods will be tried in new factories being erected. He states that it is better to adopt the latest methods to

minimise handling. This is very necessary in western countries where labour is expensive, but in the East at present the investment of large sums of money in mechanical devices may not be so readily justifiable.

In his fifth chapter the author describes the Brown Boveri electric tunnel kiln. He states in the preface that he worked at the Brown Boveri works in Switzerland during his visits abroad. The maintenance of a reducing atmosphere in part of the heating zone is said to be necessary to produce whiteness to the articles. It should be pointed out that this is only necessary when firing Continental porcelain, where the high temperature of firing makes it impossible to use a cobalt stain to produce whiteness.

The next chapter lists the more important ceramic factories in India and compares the industry with that of Great Britain, Switzerland, U.S.A., and Greater Germany. The latter includes Austria and Czechoslovakia and is presumably not up-to-date. The author advises that the development of the ceramic industries in other countries be studied before plans are drawn up for developing India's industry.

The possibility of making high-class pottery on a cottage industry basis in India is considered in a further chapter. It is stated that the reason for the poor quality of Indian crockery is the lack of a good china clay (page 51). In point of fact there are good samples of china clay available in India and they are now being used in some Indian potteries. The poor quality of the ware is not due entirely to raw materials.

The quickest way of developing Indian industries is the subject of the final chapter. In this connection thorough geological survey, hydroelectric development, and road building are recommended. Wherever possible industries should be self-sufficient. Hundreds of science students should be trained abroad, and some foreign experts imported.

The list of overseas engineering firms who supply the latest ceramic equipment will be read in this country with some surprise, since out of forty-eight firms listed only one British firm is mentioned, and that a builder of kilns. It appears to have escaped the author's notice that British firms have, and are still sending valuable consignments of ceramic machinery to his country.

The text is illustrated with several

photographs and a few well-drawn diagrams. The flow chart facing page 50 (porcelain in the heading is incorrectly spelt and there are other errors in the chart) would be improved by the omission of the kneading machine, which is being rapidly replaced in Europe by the de-airing pugmill and the intermittent kilns.

W. L. GERMAN.

**Notes on Applied Science, No. 6.**  
**National Physical Laboratory.**  
**H.M.S.O. 1s. 6d.**

The National Physical Laboratory have recently published a booklet dealing with the scientific aspects of the design and accuracy of volumetric glassware. The report traces the development of British volumetric glassware from 1914 to the present date, and states that the present high level of quality and quantity is an achievement of which the industry can be proud.

The unit generally used for the graduation of volumetric glassware is the millilitre (ml.), i.e., one-thousandth part of the litre. The capacity of a glass vessel varies with its temperature, and it is therefore necessary to define the temperature at which its capacity is intended to be correct. British Standards for volumetric glassware are referred to a standard temperature of 20° C. In tropical countries this temperature is taken as 27° C. The effect of change in temperature on the capacity of a glass vessel is, however, relatively small, amounting to three parts per 100,000 of the capacity for a change of 1° C. for vessels of soda glass, and one part per 100,000 for those of borosilicate glass. Thus a change of 7° C. results in a change of two parts per 10,000 in soda glass vessels, and with a few exceptions this is finer than the degree of accuracy associated with volumetric glassware. The important exceptions are the 1,000 ml. and 2,000 ml. one-mark graduated flasks, made of soda glass, where the change in volume for 7° C. change in temperature corresponds to the maximum possible error for flasks of the highest quality: 0.2 ml. and 0.4 ml. respectively.

To assist the construction of calibration tables, a survey of the glasses used by British manufacturers of volumetric glassware was made. From the information gleaned it appeared that the coefficient of cubical expansion previously used for soda glass, viz., 0.000026 per 1° C. was too low for the glass in current use, and it was decided to adopt the value 0.000030 for all vessels of soda glass made to British Standards. For borosilicate glasses, the coefficient of cubical expansion adopted is 0.000010 per 1° C.

**Construction**

Glass used in the manufacture of volumetric glassware should be free from distortion and other visible defects. The vessels should be well annealed and be sufficiently robust to withstand shocks received in normal usage. Any tubing which carries a graduation line or a scale should be of appropriate diameter to admit of the line or lines being readily placed in position well within the tolerance on the capacity. Jets should be made with a gradual taper without sudden constriction at the orifice. The ends of the jets should be ground off smooth and square with the axis of the tube and should be slightly bevelled.

The barrels and keys of stopcocks should be finely ground to the standard taper of 1 in 10 on diameter, and comply with the appropriate requirements as to leakage. Vessels such as flasks and cylinders should have a level base, and, when placed on a surface inclined at 15° from the horizontal, should not topple.

Graduation lines should be fine, cleanly etched, permanent lines of uniform width. They should be confined to the cylindrical portions of the glass, but where it is necessary to admit lines on tapered portions, special provision has to be made in regard to the accuracy of each individual line and method of reading. On glassware having only one or two lines, the lines should completely encircle the tube.

On all vessels (other than butyrometers) bearing sub-divided scales, the distance between adjacent lines should not be less than 1 mm. There should be no evident irregularity in the spacing. If these vessels are intended for the highest class of accuracy, every tenth line should be carried completely round the tube. The shortest lines should be carried at least half-way round the tube, and all other lines should be carried about two-thirds round the tube.

Vessels not intended for the highest class of accuracy may have their scales confined to the front face of the vessel.

When the zero volume is at the closed end of the tube, e.g., in graduated cylinders, the lowest 10 per cent. of the scale should be omitted. Where, exceptionally, this does not meet the requirements of the user, the individual "pointing" and verification of any additional lines is recommended.

Besides this information, the booklet also deals with a method of determining the capacity of volumetric glassware, and this should be of interest to the inspection departments of volumetric glassware manufacturers.

## CERAMICS

lification contains the first part of an article by M. L. Misra, the assistant professor of refractories at Benares Hindu University on the subject of "Clays, their Properties, Uses and Occurrences in India and Pakistan." The subject of the current instalment—"Clay Minerals and their Properties"—was covered in the article on page 202 of the July issue of *CERAMICS*. The other main article, by Dr. S. S. Das, lecturer in Ceramics at Benares Hindu University, is entitled, "Insulation and Fuel Saving in Intermittent Kilns." Besides these articles there are the usual news items and abstracts from most of the leading Ceramic journals.

### Pottery Quarterly, Vol. I, No. 2. Summer, 1954. 3s.

Among the articles in the latest issue of the *Pottery Quarterly* is one which contains many useful hints for the studio potter on Vegetable Ash Glazes, by Eleanor Whittall. The routine workshop visit is paid this time to the Milland Pottery, established since the war by a few enthusiasts. There are several other interesting articles and some excellent photographs, though unfortunately the plate numbers seem to have been guillotined off, making their identification less easy.

## UNIQUE SWEDISH EXHIBITION HALL

RECENTLY opened by Kosta, Sweden's oldest glassworks, and one of the two largest of the country's crystal producers, has been an exhibition hall of unique design. One of the first visitors to this combined museum and show window was King Gustav Adolf, who called there during his recent trip through the Province of Smaland, and who left his signature, written with a diamond tool, on one of its glass walls.

Incorporating not only glass walls but a glass floor this unusual building has been planned by Bruno Mathson, the well-known Swedish architect and furniture designer in collaboration with Kosta's chief designer, Vicki Lindstrand, and provides a modern setting for the display of Kosta's new products. Triple-paned, in order to keep the hall well insulated, the walls are assembled from enormous sections of fine mosaic, which shines with the hues of mother-of-pearl. The sections are anchored in copper frames. The ceiling is of plain pine deal boarding. To give protection, when necessary, against too much daylight, which comes streaming into the hall from

all sides, marquisette draperies have been arranged.

For displaying the crystal products, white and black shelves alternate with glass shelves, while black lampshades add to the effect. Hidden fluorescent tubes behind the exhibits provide artificial lighting.

In contrast to this modern setting for contemporary pieces produced by the Kosta Works is an 18th century house, with which the new exhibition hall communicates, and whose rooms form an authentic background for interesting museum pieces, which include specimens of the works' products over the 200 years of its existence.

Such is the increasing interest of tourists in the Swedish glass industry, most of whose works are located near to each other in the Smaland Province, that motor coaches run regular trips for sightseers to many of the glassworks. The new Kosta exhibition hall will now be included in the itinerary of these tours.

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**Wild-Barfield Invitation.**—During the coming winter parties of up to thirty senior engineering students from technical colleges and members of technical societies are invited to visit the Watford works of Wild-Barfield Electric Furnaces Ltd. The tour will include a visit to the production shops, where electric furnaces from laboratory units to full-scale production furnaces and induction heating equipment will be seen in all stages of manufacture. The metallurgical and chemical laboratories provide opportunity for the study of research methods and equipment, whilst the development section will afford the visitor scope for seeing many new heat-treatment processes and prototypes in the course of development.

An invitation is extended to parties of visitors from 1st September to 31st May, 1955, on a limited number of week-day afternoons (Monday to Friday), and early application is desirable to avoid disappointment.

**"Wiggin Nickel Alloys."**—The latest issue of *Wiggin Nickel Alloys* (No. 27) has just been published, and is obtainable from Henry Wiggin and Co. Ltd., Thames House, Millbank, London, S.W.1. Among the articles is one of particular interest to ceramists entitled, "Electrical Resistance Alloys." Among other interesting statements, it is alleged that the life of the 80/20 alloys in recent tests at 1,232° C. is approximately equivalent to thirty or forty times the life envisaged when the test was devised in 1933, for lower temperatures.

**F. G. Thomson.**—Staffordshire Potteries Ltd., one of the member companies in the Keele Street Pottery Group, has appointed Mr. F. G. Thomson as Commercial Manager. Although committed to very large and continuing contracts the company's two streamlined modern plants at Weir, Stoke-on-Trent, can still extend their production capacity and the aim is greatly to expand their output of domestic tableware in both home and export markets.

Mr. Thomson, who has made a close study of industrial administration, is used to large-scale marketing, and has spent many years as a senior executive in associate companies in the Tube Investments Group, and has travelled extensively in overseas markets for the companies concerned.

He took up his appointment with Staffordshire Potteries Ltd. on 1st August.



Mr. A. H. C. Wenger

**Monsanto Appointment.**—Mr. Philip A. Singleton, managing director of Monsanto Chemicals Limited, has announced that at a meeting of the board of directors held on 27th July, Mr. N. F. Patterson was appointed a director of the company. Mr. Patterson, who joined Monsanto in 1946, became works manager at Ruabon in 1947, and in July, 1949, was appointed general manager of production, with responsibility for all the production operations of the company. He is also a director of Monsanto (Soil Conditioners) Limited and Monsanto Plastics Limited, subsidiary companies of Monsanto Chemicals Limited.



Mr. N. F. Patterson

## DEATH OF MR. A. H. C. WENGER

WE have learnt with deep regret of the death of Mr. A. H. C. Wenger, chairman and managing director of Wengers Limited, Etruria, manufacturers of ceramic colours, glazes and materials.

Mr. Wenger, who was 76, had in the course of a long and active business career acquired an extensive knowledge of the ceramic and allied industries. He had been associated with Wengers since the end of the last century and was made a director in 1901. On the death of his father in 1924 he succeeded him as chairman, a position he held until his death.

Mr. Wenger, who was born in Hanley, was educated at Newcastle High School and later on the Continent. He early supported the British Ceramic Society when it was still called the English Ceramic Society, and was also a member of its American equivalent. He was a member of the Society of Glass Technology and a Fellow of the Royal Society of Arts.

In public life, Mr. Wenger served on the Newcastle Town Council and was mayor of the ancient corporation of Hanley in 1923. He was High Sheriff of Staffordshire in 1935-36 and was appointed a Justice of the Peace for Stoke-on-Trent in 1929, in which capacity he served for twenty-three years. Mr. Wenger was also a sincere churchman and devoted much of his time to the affairs of his parish church.

Mr. Wenger leaves a widow and four children.

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## PRODUCTION OF THERMOMETER TUBING

A 130 ft. tube-drawing tower for production of clinical thermometer tubing has been installed at the Wealdstone glassworks of James Powell and Sons (Whitefriars) Ltd., at a cost of approximately £12,000.

Speaking at the annual general meeting recently, Sir Graham Cunningham, the chairman, said that one of the four drawing shafts of the tower had been in production since last year with very satisfactory results and the installation would be in full production in the very near future. The new method of production substantially eliminates wasteful defects in the hand-drawn method. The firm was making efforts to find new markets abroad to take the additional production to which the new tube-drawing tower would give rise.

Dealing with the stained-glass side of the business, Sir Graham said that the demand for British craftsmanship was higher than at any time since the war.

## N.I.F.E.S. FOUR-WAY SERVICE

SPEAKING at a Press conference in London recently, Dr. W. A. Macfarlane, the chief executive of the newly-formed National Industrial Fuel Efficiency Service, said that efficient fuel usage could bring about a 20 per cent. reduction in present consumption. The resulting savings, he added, would provide for an expanding consumption on an efficient basis without recourse to importing coal.

The National Fuel Efficiency Service (N.I.F.E.S.) which was formed last May, Dr. Macfarlane explained, plans a four-way service which is set down in their recently-published booklet. This service includes "first-aid," where an engineer

looks round the applicant's plant, giving free advice, or alternatively a demonstrator gives free boiler-house instruction. The second feature of the service, "operational improvement," involves a more detailed inspection. In this case a charge is made, the cost per engineer lent by N.I.F.E.S. being £5 daily; generally for £25 a report will be supplied showing how the plant will operate at maximum efficiency. The third point of the service, "inspection in detail," involves close examination and compilation of test data, showing among other things plant potential, and performance in relation to load on plant. The fourth way in which N.I.F.E.S. will help is by a "full heat and power survey." The cost for this is the same as for the other two charged services (i.e., £5 per day per engineer actually at work on the premises). On the basis of the report drawn up, a full-scale reorganisation of a works can be planned.

Dr. Macfarlane, running through the points of the brochure, laid particular emphasis on the Government Loan Scheme, which will help industrialists to carry out N.I.F.E.S. recommendations. By this, up to £30,000 may normally be borrowed, the repayment to be spread over a period of up to twenty years, according to the rate of depreciation of the plant. Interest will be charged at commercial rates, except that loans will be interest free for the two years after the equipment has been installed.

Dr. Macfarlane, stressing the need for industries to make use of N.I.F.E.S. services, said that nine million tons of fuel could be saved annually in industry alone, or put more crudely, that "25,000 tons a day were going up the spout."

In answer to questions, Dr. Macfarlane said that 1,600 visits had been paid to firms since the formation of N.I.F.E.S. on 1st May. As a guide to their scope, he added that there were 33,000 con-

sumers of more than 1,000 tons of solid fuel a year.

Dr. Macfarlane concluded that it was their job to go out and promote fuel efficiency rather than to wait for people to ask them for their services, though those who did would naturally be helped first. He expressed the hope that they would be assisted fully in their important task.

**New Indonesian Porcelain Factory.**—Costing Rs. 3,500,000, a new large porcelain factory is to be built at Tjimahi, near Bandung, and will be operated by Bromo N.V. Personnel for the factory are now being trained at the Ceramics Research Institute at Tjijadas, Bandung, under the supervision of two Japanese experts. It is expected that the new factory will begin operations later this year.

## EDUCATIONAL

### NORTH STAFFORDSHIRE TECHNICAL COLLEGE, STOKE-ON-TRENT. CERAMICS DEPARTMENT.

Principal: H. W. Webb, O.B.E., D.Sc., F.R.I.C., M.I.Chem.E.  
Head of Department: W. L. German, M.Sc., Ph.D., F.R.I.C.

### COURSES IN THE MANUFACTURE OF POTTERY, BUILDING MATERIALS, REFRactories AND VITREOUS ENAMELS. SESSION 1954-55.

Classes begin Monday, 20th September, 1954.

Interviewing week: 6th to 10th September inclusive.

**FULL- and PART-TIME DAY and EVENING CLASSES** are provided in the above subjects.

**THE FULL-TIME DAY COURSE** is of three years' duration (consisting of six months' full-time attendance at the College and six months on a factory in each year) leading to the College CLAYWORKS MANAGER'S CERTIFICATE and the POTTERY MANAGER'S CERTIFICATE, which are recognised both at home and overseas, and also the DIPLOMA IN CERAMICS. The subjects include THEORETICAL and PRACTICAL CERAMICS, FUELS, CLAY ENGINEERING, POWER UTILISATION, CHEMISTRY and PHYSICS, and MANAGEMENT SUBJECTS. Specialisation in either Pottery, Refractories, or Building Materials is provided for.

A similar full-time course is also available in VITREOUS ENAMELLING, and includes METALLURGY.

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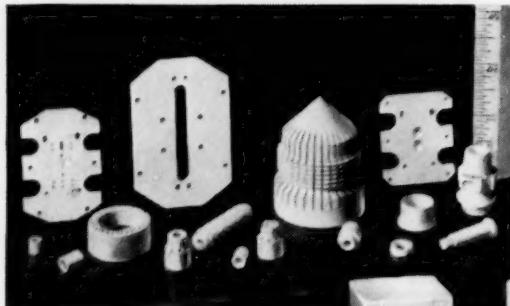
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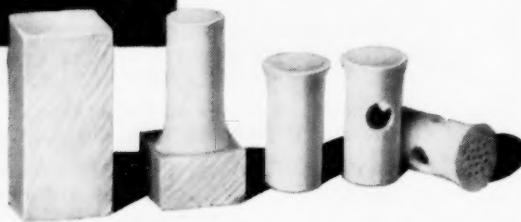


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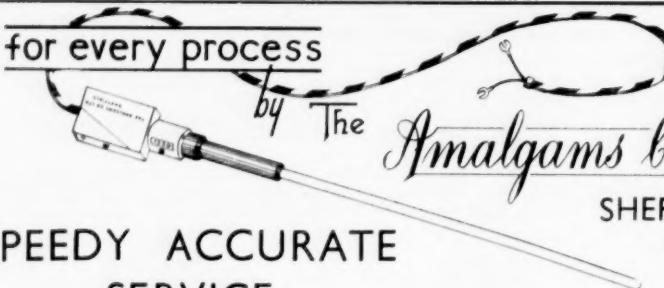
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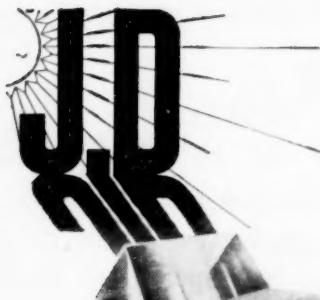
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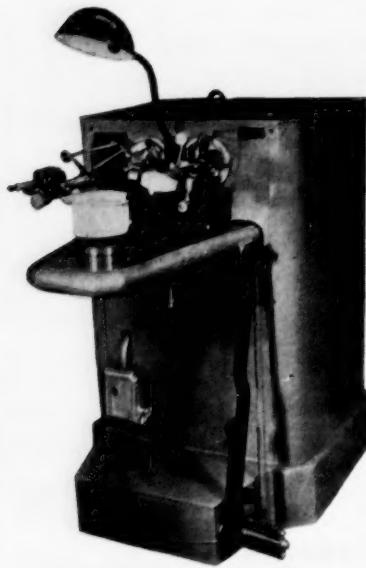
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